NAVAL POSTGRADUATE SCHOOL
Monterey, California

DTIC QUALITY INSPECTED 4

THESIS

INTERNETWORKING:
ECONOMICAL STORAGE AND RETRIEVAL
OF DIGITAL AUDIO AND VIDEO
FOR DISTANCE LEARNING

by

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September, 1996

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE Sep 1996	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE INTERNETWORKING: ECONOMICAL STORAGE AND RETRIEVAL OF DIGITAL AUDIO AND VIDEO FOR DISTANCE LEARNING

5. FUNDING NUMBERS

6. AUTHOR Michael E. Tiddy

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT

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Large, distributed organizations such as the Naval Service can economically benefit from use of the MBone and its associated tools. To date, Navy and Marine Corps projects using video teleconferencing have not exploited the vast possibilities provided by the Internet and the MBone. This thesis takes distance learning one step farther and combines MBone audio/video with the new recording tool called the Multicast Backbone Video Conference Recorder (MBone VCR). This enables distance learning as a viable replacement to on-site training. It is technically feasible and economically supportable to record the digital media that results from an MBone session used for a distance learning program. That stored information can then be used repeatedly and easily updated to support changing curricula and information. Problems and network-accessible solutions are demonstrated in this case study on use of the MBone VCR as a usable remote educational tool.

14. SUBJECT TERMS Multicast Backbone, MBone, Distance Learning, Video Teleconferencing, Video Archiving, World-Wide Web

15. NUMBER OF PAGES 119

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

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INTERNETWORKING: ECONOMICAL STORAGE AND RETRIEVAL OF DIGITAL AUDIO AND VIDEO FOR DISTANCE LEARNING

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 1996

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Large distributed organizations such as the Naval Service can economically benefit from the use of the Multicast Backbone and its associated tools. To date, Navy and Marine Corps projects using video teleconferencing have not exploited the vast possibilities provided by the Internet and the MBone. This thesis takes distance learning one step farther and combines MBone audio/video with the new recording tool called the Multicast Backbone Video Conference Recorder (MBone VCR). This enables distance learning as a viable replacement to on-site training. It is technically feasible and economically supportable to record the digital media that results from an MBone session used for a distance learning program. That stored information can then be used repeatedly and easily updated to support changing curricula and information. Problems and network-accessible solutions are demonstrated in this case study on use of the MBone VCR as a usable remote educational tool.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACM	Association for Computing Machinery
ANSI	American National Standards Institute
AGI	Automatically Generated Indices
ATM	Asynchronous Transfer Mode
AVT WG	Audio Video Transport Working Group
CGI	Common Gateway Interface
DoD	Department of Defense
E-mail	Electronic Mail
FAQ	Frequently Asked Questions
FPS	Frames Per Second
FTP	File Transfer Protocol
GB	Gigabyte
GUI	Graphical User Interface
HTML	Hyper-Text Markup Language
HTTP	Hyper-Text Transfer Protocol
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IIRG	Information Infrastructure Research Group
IP	Internet Protocol
JPEG	Joint Photographic Experts Group
Kbps	Kilobits Per Second

KBps	KiloBytes Per Second
LAN	Local-Area Network
LBNL	Lawrence Berkeley National Laboratory
Mbps	Megabits Per Second
MERCI	Multimedia European Research Conferencing Integration
MICE	Multimedia Integrated Conferencing for Europe
MPEG	Motion Picture Experts Group
mrouter	Multicast Router
NFS	Network File System
NPS	Naval Postgraduate School
NTSC	National Television Standards Committee
PC	Personal Computer
RTCP	Real-Time Transfer Control Protocol
RTP	Real-Time Transfer Protocol
sdr	Session Directory
TCP	Transmission Control Protocol
TTL	Time-to-Live
UDI	User Defined Indices
URL	Uniform Resource Locator
UCL	University College London
UDP	User Datagram Protocol
VCR	Video Conference Recorder

WAN	Wide-Area Network
wb	Whiteboard
WWW	World Wide Web
vat	Visual Audio Tool
vic	VIdeo Conference
VTC	Video Teleconferencing
VTT	Video Teletraining

ACKNOWLEDGMENTS

The author would like to acknowledge the hard work done by Wieland Holfelder on the MBone VCR. Wieland initially developed the VCR during a 15-month stay working with the tenat group at the International Computer Science Institute (ICSI) in Berkeley, California. Since his return to Germany he has feverishly worked to improve the tool and make it compatible with the new real-time transport protocol (RTPv2). Without his persistence and patience this thesis might not have gotten off of the ground.

The author would also like to recognize the continuing work being done on perfecting the MBone tools. Van Jacobson and Steven McCanne (of the Information and Computing Science Division at the Lawrence Berkeley National Laboratory, LBNL) and Steve Deering (of the Xerox Palo Alto Research Center), three of the principal creators of MBone, have provided the world with an excellent set of educational tools.

Finally, the author sincerely appreciates the guidance of his thesis advisor: Don Brutzman, whose own persistence was an excellent example to follow when things seemed impossible.

I. INTRODUCTION AND MOTIVATION

This thesis investigates the usefulness and feasibility of applying networked storage of digitized audio and video, all via the Multicast Backbone (MBone) for distance learning. The research follows the "Recommendations for Future Work" section of the thesis "Internetworking: Worldwide Multicast of the Hamming Lectures for Distance Learning" (Emswiler, 1995).

A. BACKGROUND

The idea of face-to-face meetings without the need for travel has intrigued educators and business leaders for years. Science-fiction television dating back to the 1960's has portrayed the future as one in which people will routinely communicate over great distances using audio and video. Distance education has recently been considered in much the same way. With impressive advances in data compression, real-time transport protocols and transmission media, the future seems to have arrived. Today people across the globe can come together using the Internet and effective audio/video software tools that utilize a virtual network called the Multicast Backbone (MBone).

The MBone uses audio-visual conferencing capabilities that were developed to provide scientists with an easy way of sharing information over long distances in a manner similar to their normal interactions--and in their normal workplaces. The MBone was also developed to prove the potential usefulness of this kind of interaction on a scale provided by the Internet. The MBone effort has effectively helped set standards that can guide interoperable software development (Davies, 1995).

Since it began, the MBone has proven to be an important tool in remote conferencing. However, most of the events last one day or perhaps a week and are not broadcast on a regular production basis. In the first quarter of 1995, Tracey Emswiler of the Naval Postgraduate School succeeded in multicasting an extended class over the Internet (Emswiler, 1995). Her case study involved multicasting Dr. Richard Hamming's course, "The Art of Doing Science and Engineering: Learning to Learn," three times a week for an entire academic quarter. Emswiler correctly pointed out that storing and accessing digital recordings of past lectures and conferences is the next step in the evolution of this technology.

B. MOTIVATION

1. What is the Importance of Distance Learning and the MBone?

"The organization that learns fastest will survive" (Senge, 1990). This philosophy is often forgotten in a cost-cutting era that continuously attempts to do more with less. When an organization is facing shrinking budgets and increasing costs, training programs are often the first to receive cuts. Training is also set aside when operational commitments take students away from local training centers. Due to widespread geographic dispersion, military personnel often fall victim to the philosophy of "I'll go to the class when I get back from deployment." Distance education is intended to provide an alternative to the usual requirement of a student's physical presence at school for training. If successful, distance education can reduce training budget expenditures reducing the need for travel.

The MBone, using the existing Internet infrastructure, provides an interactive way to teach and learn. MBone software is economical (the tools are free). It can be used to provide real content today and software capabilities continue to gain strength. Applied to distance learning, the MBone provides geographically remote students the ability to economically and dynamically interact with the teachers and other students using audio, video, and other protocol streams. The convergence of all types of information content on the Web means that Internet access has become a crucial requirement for all organizations for the foreseeable future. Multicast and the MBone are the best technical solutions for delivering Internet-compatible audio and video.

2. How does Video Archiving Apply to Distance Learning?

Distance learning effectiveness improves not only when long distance can be overcome, but also when the timing of classes is no longer a limiting factor. Establishing a video archive of the classes that are held over the Internet using the MBone can provide a means for students to view classes at their convenience. Students on another continent will not have to watch the instructor at 3 A.M. in their local time zone. Instead, they can watch the lecture when convenient and ask any question using electronic mail. It will actually bring the classroom to the student anytime it is necessary (Emswiler, 1995).

Internet-based distance learning is not a panacea. Significant human-factors and other issues exist regarding pedagogy, effectiveness and ease of use (Gabrino, 94). We do not explicitly address those issues in this thesis. Rather, we focus on the technical feasibility of recording and distributing digitally archived network-accessible audio/video. Further work is needed to maximize the effectiveness of this new medium.

C. THESIS ORGANIZATION

This thesis is organized into the following chapters. Chapter II discusses the background of this work and other research related to distance learning, the MBone, and video archiving. Chapter III provides a short synopsis of the problems examined in this thesis and applications of the results. Chapter IV examines the protocol and payload types used for digitizing the desired lectures and conferences. Chapter V explores the methods used for building and accessing the archive. Chapter VI shows the experimental results of this research. Chapter VII summarizes the conclusions drawn from this work and provides recommendations for future work.

Appendices have been provided for further clarification of concepts addressed in this thesis. Appendix A is a glossary of terms used in this thesis. Appendix B provides the HTML and *perl* Web scripts that are used during video retrieval. Appendix C is an instruction set for installing and operating the tools used for video storage and retrieval. Appendix D shows two recent articles that detail MBone and Web content work that is continuing at NPS.

II. BACKGROUND AND RELATED WORK

A. INTRODUCTION

This chapter examines pertinent background work and continuing research in distance education and the Multicast Backbone (MBone). A short summary of each study is provided to explain how they relate to this thesis.

B. BACKGROUND

1. Distance Education

In order to understand the possible applications of the Multicast Backbone and video archiving, the term distance education or distance learning must be defined.

> Distance education is a special application of telecommunications to teaching and learning situations in which learners are geographically separated from teachers, and both depend on electronic devices to communicate (Keegan, 1983).

Distance education can thus be seen as something as simple as a correspondence course offered through electronic mail or something as complex as interactive video teleconferencing via satellite.

Distance education does have its limits. Understanding when a distance education approach might work is crucial to any implementation. Applications that require extensive hands-on training are not the best candidates for distance learning. Yet something like "Math for Marines" (a correspondence course) might easily be taught using distance education. The list in Figure 2.1 outlines general situations when a distance education approach can be productively applied.

- ♦Target audience is widely scattered and it is not cost effective or possible to have them travel to a central training location.
- ♦Content or consistency in delivery is so critical that it must be carefully controlled for accuracy or correct interpretation.
- ♦Content is too dangerous for novices to participate in and distance education will allow for familiarization and confidence building prior to the actual situation.
- ♦Scheduling difficulties arise because the student cannot take extended time from other critical missions to attend a normally conducted training program.
- ♦The expense of conducting live training is cost prohibitive.
- ♦There are a limited number of qualified trainers.

Figure 2.1 Productive applications of a Distance Education approach. (Biggs, 1994)

2. Multicast Backbone (MBone)

Video Teleconferencing (VTC) has been the method chosen for many past experiments in distance learning. However, this method requires dedicated transmission lines, special proprietary hardware and (usually) a dedicated VTC classroom. While there have been several alternative VTC technologies to choose from, all have these costly minimum requirements. The biggest question when trying to implement a distance learning program is which alternative is the most cost effective.

Since 1992 a new Internet development known as the Multicast Backbone (MBone) has been growing in popularity. The MBone was first used to broadcast the March 1992 Internet Engineering Task Force (IETF) conference. Since then, it has been used for numerous global presentations. Primarily, the MBone has been used by network researchers to collaborate with each other. It offers a number of advantages over standard

teleconferencing, which instead joins very few sites with expensive dedicated transmission lines. MBone links anyone to the Internet who has a workstation or PC and a high-speed connection. The increased flexibility of the MBone has resulted in moves by both NASA and DOE to replace teleconferencing with MBone meetings (Kahn, 1994).

Multicasting gained international attention (and made rock-and-roll history) when it was used to carry 20 minutes of the Rolling Stones' "Voodoo Lounge" concert tour. The concert was carried to some 200 workstations around the world that were connected to the Internet. Another example of its potential was seen at a surgeons' conference at the University College in London (UCL). Approximately 100 doctors in London and Sweden watched as a surgeon in San Francisco performed a complex liver operation. As he operated, viewers asked questions about the procedure (Davies, 1995). The MBone has also provided around-the-clock coverage of space shuttle flights. In effect, the MBone provides free, many-to-many video teleconferencing over the Internet.

Specifically, the MBone is a subset of the Internet that is capable of multicasting. That is, instead of sending identical multiple sets of packets to each destination (like delivery of an electronic mail message with multiple recipients), the network copies each packet of information from the source and delivers the packets only to those destinations that have requested them. The receivers request the packets by subscribing to particular sessions. The receiver must be on a network set up for multicasting to be able to sign up for a session. Since multicasting capabilities are not built into much of the Internet, the MBone is considered a virtual network. It does use the same physical topology as the Internet. However, real-time audio and video packets can require special handling, and

therefore are distributed using a network of routers that know what to do with multicast packets.

Van Jacobson and Steven McCanne (of the Information and Computing Science Division at the Lawrence Berkeley National Laboratory, LBNL) and Steve Deering (of the Xerox Palo Alto Research Center) are three of the principal developers of the MBone. The team created the software tools used most during MBone multicast (Kahn, 1994). Unlike traditional broadcast methods such as radio or television, the MBone is totally interactive. The software created by the development team includes a session directory to announce events, a shared virtual piece of paper called whiteboard (wb), a video conferencing tool, and an audio tool. The software enables real-time audio-video conferencing over the Internet. Participants can interact using text, images and face-to-face communication.

Since its inception MBone conferencing has grown exponentially, with traffic doubling about every eight months. Right now, more than 10,000 people in 30 countries are using it for collaborative work. "Among scientists," predicts Stewart Loken, who heads LBL's Information and Computing Sciences Division, "MBone conferencing will become as routine as e-mail. And this will happen much sooner than you think." (Kahn, 1995) Despite its steady growth, special routing and bandwidth requirements have made the MBone somewhat difficult to access. However, new router software is coming onto the market that simplifies connecting to the MBone. MBone connectivity is now possible over slower links such as 128 Kbps Frame Relay (Erdogan, 1996), and its use appears imminent on 128 Kbps ISDN links (Mihlon, 1996). Other advances in the technology that

allow recording and remote playback of MBone sessions are also being researched (Holfelder, 1996). This type of approach can allow individuals to watch recorded sessions at any time, making the sessions more convenient and accessible to people in different time zones.

Today, no other interactive communications tool has been as successful at reaching large numbers of people. Primary reasons for this success include public-domain software for multiple platforms, and efficient many-to-many packet delivery using multicast. With small advances in hardware and software anyone with a computer and an Internet connection will be able to use the MBone. Says Loken, "On the Internet, I believe that 1995 will be to MBone what 1994 was to the World Wide Web. Almost unknown right now, Internet videoconferencing is about to become commonplace." (Kahn, 1995) It is now 1996 and the MBone continues its rapid growth. Getting connected remains labor intensive, but it is a one-time job. It appears that MBone expansion has not crossed over into explosive growth, but the steady exponential increase remains impressive.

C. RELATED RESEARCH

1. Merci Project: Multimedia European Research Conferencing Integration

The Multimedia European Research Conferencing Integration (MERCI) project is a follow-on to the Multimedia Integrated Conferencing for Europe (MICE) project, each coordinated by UCL (MERCI, 1996). MICE provided multi-way integrated conferencing service between a number of European pilot sites, linking various sites to the appropriate

communities in the U.S. MICE demonstrated a range of possible ways to internetwork project partners using heterogeneous computing environments. The result was the interconnection of up to half a dozen conference rooms, up to a dozen workstations, and the employment of conferencing services between them. In September of 1995 the MICE project gave way to the Multimedia European Research Conferencing Integration (MERCI) project.

The objective of the MERCI project is to provide all the technology components (other than the underlying data network itself) to allow proper deployment of software tools for European multimedia collaboration. Figure 2.2 shows how MERCI is making improvements to the tools developed during the MICE project from 1992-95.

- ♦Better integrated facilities, so more easily used by untrained users
- ♦Better capability for higher quality video, audio and shared work space facilities
- ♦Inter-operable cross-platform support for many systems - UNIX workstations, PCS and MACs
- ♦Better support for the introduction into and recording of multimedia information in conference
- ♦Support for different network technologies - mainly over IP: packet-switched, ATM or SMDS and ISDN
- ♦Inter-operation between workstations running the multicast Internet and the normal CCITT procedures
- ♦Facilities for secure conferencing - with easy distribution of keys and information
- ♦Distributed measurement, monitoring and control

Figure 2.2 Planned MERCI improvements to MICE project tools. (MERCI, 1996)

The expected benefits for the users of the MERCI applications are to set a standard of excellence for audio/visual techniques and shared whiteboard in tele-teaching, remote consultation of doctors, and many other similar disciplines. Industrial organizations are also expected to investigate how businesses can be helped by the technology. The details of the MERCI project can be found at *http://www.cs.ucl.ac.uk/mice/merci/merci_desc.html*.

2. Anders Klemets: WWW Media-on-Demand System

This research shows that supporting the playing of continuous media by using external programs controlled by a WWW client is possible (Klemets 1994). Klemets' paper describes the design and implementation of a unicast "Media on Demand" server that uses WWW as its user interface. Offered media include audio and video recordings of transmissions on the Internet Multicast backbone (MBone), and arbitrary prerecorded audio files developed during the MICE project. More information on this research can be found at: *http://www.it.kth.se/~klemets/vatplay.html*

3. Video Mosaic (Vosaic)

This research addresses the problem of the lack of architectures that encourage the efficient reuse of continuous media, such as video and audio (Chen, 1995). The researchers propose a continuous media model that extends the architecture of the WWW to encompass the dynamic, real-time information space of video and audio. Their new WWW browser, Vosaic, short for Video Mosaic, incorporates real-time video and audio into standard hypertext pages that are displayed in place. They show that real-time video and audio data can be effectively served over the present day Internet with the proper

transmission protocol. With that, they have developed a real time protocol called VDP that specializes in handling real-time video over the WWW. VDP reduces inter-frame jitter and dynamically adapts to the client CPU load and network congestion. The WWW server dynamically changes transfer protocols, adapting to the request stream and the meta-information in requested documents. More information and the server and browser software are available at *http://choices.cs.uiuc.edu/Vosaic/Vosaic.html*.

4. Murat Tamer: Multicast and ATM Network Prerequisites for Distance Learning

The basic problem examined in this thesis is how the Multicast Backbone and the audio and video tools can be used effectively for distance education (Tamer, 1996). Here, the key to effective use is good audio/video quality through Internet connections with simple, cost-effective configurations. The focus will be on showing schools that do not have great financial resources how to enter and use the MBone for their own distance education programs. This thesis can be found online at:

http://www.stl.nps.navy.mil/~iirg/tamer/thesis.html

5. Ridvan Erdogan: Implementation of Multicast and MBone Over Frame Relay Networks

This is a thesis that shows the implementation of the MBone over Monterey BayNet for educational purposes (Erdogan, 1996). It documents the need for and the necessary reconfiguration of Monterey BayNet sites to join the MBone. It shows that MBone over Frame Relay networks is possible and that the current MBone technology

provides satisfactory performance even on low-speed (128 Kbps) network connections. This thesis can be found online at: *http://www.stl.nps.navy.mil/~iirg/erdogan/thesis.html*

6. Robert Norris and Dave West: The Digital Library Phenomenon: Opportunities and Implications for the Naval Service

This thesis examines the emerging field of work encompassed by the term "Digital Library" and offers a plan for developing a Naval Service Digital Library (Norris, West, 1996). Digital resources such as books, magazines, and videos are all part of this plan. Archived MBone easily fits into the Digital Library concept by providing easy to use, online video lectures and conferences for educational purposes.

7. Wieland Holfelder: MBone VCR on Demand Service

This architecture is a separate project that planned to have a java based client that has access to an MBone VCR server over a CORBA compliant protocol and can request recordings and playbacks from the server (Holfelder, 1996). The server will and announce playbacks so other MBone-participants have access to them. This project is part of continuing research into the use of MBone VCR by Wieland Holfelder and his research group at the University of Mannheim.

III. PROBLEM STATEMENT

A. INTRODUCTION

This chapter gives an overview of what pieces of the distance learning puzzle are missing and what software tools can be used to fill in those pieces. The chapter goes on to discuss where MBone archiving fits into distance learning and how such an archive might be put to use in the Naval Service and the Department of Defense as a whole.

B. OVERVIEW

Video conferencing is already widely used for remote participation in meeting and classroom settings. With many commercial products available for conducting video conferences and video classes over the Internet, it is becoming the communication medium of choice for remote participation. The MBone is one of the most-used systems to send and receive audio and video over the Internet. The focus of this thesis is to show how to store and retrieve multicast sessions using the real-time audio and video tools available today, all in an economically feasible way.

1. Why the MBone?

While the Multicast Backbone is a fairly new technology, it is already widely used. The MBone is well suited to large, distributed presentations. It uses network bandwidth efficiently and allows participants to join and leave a conference easily. Remote seminar participants can receive audio, video and, in some cases, whiteboard information. Additionally, interactive audio communication is possible between the lecturers and

remote participants (Rettinger, 1995). Several studies have shown that the MBone can support real-time classrooms, thus overcoming the distance issues in distance education and remote conferencing (Tamer, 1996).

2. What is Missing?

The real-time aspect of the MBone does not eliminate any of the time constraints that a traditional classroom setting imposes on its students. Considering the world-wide reach of the MBone, time zone differences become a major factor when scheduling multicast sessions. A student on another continent watching an event in the United States typically must forego sleep to take part in the event. The main question then becomes: Can the tools available today provide archived MBone sessions that can be watched at the users convenience?

C. MULTICAST BACKBONE VIDEO CONFERENCE RECORDER (MBONE-VCR)

The recent development and use of the Real-time Transport Protocol (RTPv2) has greatly increased the efficiency of real-time conferencing on the MBone. As this protocol is refined further, the MBone will continue to expand and its reach across the globe, further reducing the need to be in the same location as a conference or class.

The MBone VCR was developed as a tool to allow MBone conference members and participants to record content for later playback (Holfelder, 1995). This new tool, which is compatible with the real-time transport protocol (RTPv2), adds more functionality to the set of multicast backbone tools and can aid in the elimination of restrictions imposed by time zone differences of remote conference participants. Chapter

IV provides a closer look at the MBone VCR. Appendix D provides the instructions needed for basic operations of the MBone VCR.

D. MBONE ARCHIVING AND RETRIEVAL

The immediate goal of this project was to store the Hamming lecture series using the MBone VCR. An archive of those files is being created to allow for two different types of retrieval: ftp and real-time streaming. By setting up this archive and allowing a remote client to start the playback of any of the recorded sessions, we have attempted to remove another obstacle to the acceptance of distance learning as an educational tool.

One obstacle that has to be overcome for the on-demand rebroadcast of MBone sessions is that of resource allocation. Since the MBone has an agreed-upon global bandwidth of only 500 Kbps, the number of individuals allowed to play back a session at one time will be limited by existing MBone events. In order to avoid the abuse of the session playback, the author recommends a single permanently dedicated global MBone session for use by the MBone VCR. The retrieval scripts used during playback will check for current use of the dedicated session and only start transmitting if the session is unused. The scripts will further limit the maximum number of sessions that can be played at one time to one global session (ttl=127) and two local campus sessions (ttl=15). There are no restrictions on the simultaneous number of file retrievals via ftp (other the by network congestion and user patience. Chapter V has a detailed discussion of the retrieval methods offered by the results of this research.

E. DOD APPLICATIONS OF THE MBONE ARCHIVE

The applications of an MBone archive go hand-in-hand with those used every day for the MBone itself. However, the archive adds one step past that of offering a class or conference to anyone in any place. It adds the flexibility of viewing the conference at any time. The number of individuals involved in formal education and number of conferences that require participants to travel to another location are two of the biggest considerations when contemplating the applicability of the MBone and the MBone VCR.

There are large numbers of DoD personnel (both trainees and instructors) involved in formal courses of instruction throughout each fiscal year. The costs involved in training personnel through a formal instructional environment include travel pay and allowances for students and instructors that are not performing regular duties, administrative support of students and instructors, and operation and maintenance of training centers. Many of the same costs apply to individuals that travel to participate in conferences around the globe.

As the MBone becomes more accepted as a standard for distance education and remote conferencing and the inconvenience of viewing classes is lessened, large savings can be achieved. Personnel will be able to participate in remote training classes and conferences either at the time of the original broadcast or later when it fits into their schedule. Thus, for many types of training and conferences, and with pedagogical improvements in online class preparation and delivery, we expect the need to be in a particular location will be eliminated.

F. SUMMARY

The software tools available today make the idea of a usable MBone archive entirely possible and economically supportable. This chapter briefly discusses where the idea of MBone archiving comes from, and how it applies to the overall goal of improving the quality of distance education. This chapter also shows how the ideas discussed in this thesis have possible far-reaching implications, not only in the Naval Service but throughout the entire Department of Defense and academic community.

IV. DIGITAL TRANSPORT ISSUES

A. INTRODUCTION

This chapter briefly outlines the reasons leading to the formation of the AVT WG and how the Real-time Transport Protocol (RTPv2) attempts to solve the bandwidth issues related to transporting audio and video over the Internet. It also reviews the most commonly used MBone tools and describes the features of the MBone VCR.

B. BACKGROUND

Due to bandwidth constraints, real-time audio and video over the Internet is a difficult proposition. At the same time, teaching a class or holding a meeting over a network requires real-time interactivity and adequate picture quality. Private networks accomplish this by using proprietary VTC protocols and high-speed dedicated links. The Internet is a media shared by millions of users and it cannot easily support the high bandwidth required for real-time audio and video. To solve this problem, many commercial products made for relative low-bandwidth video conferencing over the Internet have recently become available. Even with these products, the limited bandwidth of the Internet cannot support the entire potential demand for real-time service. There is a real possibility of severe network congestion problems caused by indisciminate use of poorly designed real-time tools. Thus the Internet Engineering Task Force (IETF), the standardization body of the Internet, saw a need to establish a standard protocol for real-time data transport.

The Audio-Video Transport Working Group (AVT WG) within the IETF has been charged with developing a protocol that facilitates the transport of digitized real-time data (such as interactive voice and video) over packet-switched networks (i.e. the Internet). Through their efforts, the use of live audio and video across networks continues to become more and more efficient. In January of 1996 the AVT WG published a Request for Comments detailing a real-time transport protocol (RTPv2) that is widely used in the software tools available for the MBone.

C. REAL-TIME TRANSPORT PROTOCOL VERSION 2 (RTPv2)

The Real-time Transport Protocol (RTPv2) developed by the AVT WG is intended to provide standardization of streaming packet header formats (IETF RFC 1889, 1996). RTPv2 is intended to support improved end-to-end network transport functionality suitable for applications transmitting real-time streams (such as audio, video, or simulation data) over multicast or unicast network links. However, RTP does not provide a guaranteed quality of service (QoS). Therefore, a separate Real-time Transport Control Protocol (RTCP) provides the augmentation needed to monitor the delivery of the data). Another issue not addressed by RTP is that of resource reservation. RTCP is sufficient to meet quality of service QoS goals during some sessions, but it will not necessarily provide support to all of the communication control requirements of any one application. Instead, if desired, RTP/RTCP relies on resource reservation protocols for QoS support, which go beyond the scope of this thesis. (IETF RFC 1889, 1996)

RTP and RTCP are designed to be independent of the transport and network protocols used in a system. Therefore, as long as the underlying network supports

multicast distribution, RTP supports the data transfer. The efforts to make RTP transport and network independent will allow its use over many protocols. RTP is even currently in experimental use directly over Asynchronous Transfer Mode Adaptaion Layer 5 (AAL 5).

Analog audio and video sources must be digitally encoded before transmitting them using RTP. There is a set of default payload types that are mapped to particular audio and video encodings. The set up of the protocol allows sources to emit only a single RTP payload type. Currently defined payload types carry either audio or video. This allows a participant to separate the reception of audio or video if the network bandwidth cannot handle both. Figure 4.1 shows the current encodings that are mapped to payload types.

Audio Payloads		**Video Payloads**
1016 (CELP)	LPC	Cell B
G.721	MPA	JPEG
G.722	PCMA	H.261
GSM	PCMU	MPV
L8	VDVI	MP2T
L16		nv

Figure 4.1 Audio/Video Encodings Mapped to RTPv2 Payload Types (IETF RFC 1890,1996)

Additional payload types can be defined dynamically with the use of conference control applications that are separate from RTP and RTCP. Multiple RTP sessions can be used in parallel to send multiple media types. Timing information carried in the RTCP packets is used for synchronization (IETF RFC 1890, 1996). This capability is used by MBone VCR to synchronize separately stored audio-video streams.

D. MULTICAST BACKBONE (MBONE) SOFTWARE TOOLS

The following sections describe some of the most popular, free MBone applications available for use on almost any computing platform. To make use of the conferencing tools, a LAN must support IP Multicast and (ideally) be connected to the MBone.

1. Session Directory (*sdr*)

The session directory (*sdr*) tool is used to advertise and manage the individual MBone sessions. It lists the available sessions, is used to create new sessions, and provides detailed additional information on each session that is listed. The session directory tool also provides the functionality to launch the appropriate viewing tools needed to watch (and listen to) any session listed. The latest versions of *sdr* have a record button that is supported by a separate shell script program (*record_session*) facilitating launch of the MBone recording tool, MBone VCR.

An earlier independently developed session directory (*sd*) tool is also available (Wood, 1996). Currently, *sdr* use and functionality is much broader that that of *sd*.

2. Video Conference (*vic*) Tool

The *vic* video tool, developed at the Lawrence Berkeley National Laboratory (LBNL) is used to transmit and receive video over the MBone. It is based on RTPv2 and can be used in a point-to-point environment. However, it is primarily intended for use in multicast/multiparty conferencing environments. *vic* is backward compatible with RTPv1 and can interoperate with both *nv* (v3.3) (Frederick, 1996) and *ivs* (v3.3) (Turletti, 1996), other video tools developed at separate labs. (McCanne, Jacobson, 1996)

vic includes the H.261 video compression algorithm which can achieve frame rates 2-4 times better than that of previous video tools. This is accomplished using a sophisticated compression technique that replenishes only the blocks of the picture that change. Using cues from the audio tool, *vic* also has the ability to switch the active viewing window among multiple simultaneous video sources to whichever source is speaking. (McCanne, Jacobson, 1996)

3. Visual Audio Tool (vat)

The visual audio tool (*vat*), also developed at LBNL, is a real-time audio application. Like *vic*, it is based on RTPv2 and can be used in a point-to-point environment. *vat* is also primarily intended for multicast/multiparty conferencing environments. (Jacobson, McCanne, 1996)

4. Robust Audio Tool (*rat*)

rat is an RTPv2-compliant MBone audio tool, available for SunOS, Solaris, IRIX and Windows-95 platforms (UCL, 1996). It is developed by the Department of Computer Science, University College London (UCL) in the United Kingdom. *rat* can interoperate with *vat* v.4.0 and has a packet-loss protection mode using redundant encodings (i.e. forward error correction - FEC) which provides enhanced performance during conditions of packet loss. *rat* is similar to existing audio tools (such as *vat*) but offers the extra functionality listed in Figure 4.2.

We have found that the redundancy feature is very powerful and provides significant improvement in audio quality even in conditions of 10% packet loss. The addition of FEC on a per-packet basis is offset by *rat* slightly reducing the default

- ♦Redundancy (packet loss protection) using forward error correction (FEC) encodings
- ♦Improved statistics
- ♦Voice / picture synchronization option
- ♦Improved hands-free performance option

Figure 4.2 Extra Functionality Offered by *rat* (UCL, 1996)

sampling rate so that total bandwidth and packets-per-second rate is unchanged (Handley, 1996). No redundancy compatibility is currently planned with *vat* due to different internal buffering schemes used in each tool.

5. Shared Whiteboard (*wb*)

The shared whiteboard application can be used as a shared drawing surface which can also import, export, and view both plain text and Postscript files (Jacobson, McCanne, 1996). *wb* facilitates non-audio interaction and can be used to reliably distribute moderately large postscript copies of a speaker's slides. Viewers can easily watch and listen to the speaker using video and audio while simultaneously viewing the slides and annotating questions using *wb*.

E. MULTICAST BACKBONE VIDEO CONFERENCE RECORDER (MBONE-VCR)

This application is designed and developed for use on the Internet's Multicast Backbone (MBone) (Holfelder, 1995). It reads cached session advertisement data from the active session directory tool (*sd* or *sdr*) that allows the importing of MBone sessions directly to the VCR. A graphical user interface (GUI) is used to control recording and

playback of sessions sent over the MBone. The VCR stores these sessions by synchronizing different media streams based on information provided by RTP. It also permits indexing and random access within recorded sessions. A command language enables user-independent MBone VCR programming features, e.g. to schedule recordings or playbacks at arbitrary times. RTPv2 information is used during the playback of recorded sessions. The MBone VCR sends the audio/video data streams out on a multicast network address/port combinations, recovering the original timing of all the media streams included in a session and advertising the same encoding protocols used by the original applications from which the data was recorded (Holfelder, 1995). Once playback has started, the user views the session with the same tools (e.g *vic* and *rat* or *vat*) used in the original multicast session that was recorded.

Users of the MBone VCR are provided with a GUI that looks like the control panel of a standard video cassette recorder. The ease of use provided by this interface enables even first-time users to operate the basic MBone VCR functions. Another important feature of the MBone VCR is that it allows the alteration of the scope (i.e. ttl) of the session playback. The user is thus able to determine whether the playback is intended for a smaller or larger (e.g. local ttl=15 or global ttl=127) audience than the original multicast. Appendix D provides instructions on the operation and use of the MBone VCR tool.

These features of the MBone VCR add significant new functionality to the current MBone application software suite. Through the use of the MBone VCR, three important benefits are achieved: (1) independence from application-specific details, (2)

use of already invented and implemented software tools for playback and (3) off-line teleconferencing support, since sessions can be recorded and sent out at a later time reaching audiences in various time zones. (Holfelfer, 1995)

F. SUMMARY

This chapter summarizes the issues relating to problems transporting audio and video from one site to another. It discusses how the bandwidth problem lead to the formation of the Audio-Video Transport Working Group (AVT WG) and provides a discussion of the Real-time Transport Protocol (RTPv2) the group has developed. Next, the chapter goes on to review the features of the most-often-used Multicast Backbone tools. This is followed by a discussion of the Muticast Backbone Video Conference Recorder (MBone VCR), its features and how it can add to the usefulness of the MBone as an educational tool. Chapter VI details the experimental results from the use of these tools and Appendix C provides instructions for the basic use of the MBone VCR.

V. ARCHIVING / STORAGE / ACCESS ISSUES

A. INTRODUCTION

This chapter gives the background of the research documented in this thesis and addresses the issues that relate to building an MBone archive. It further describes the two types of access planned for the archive. Finally it examines the bandwidth issues related to transmitting sessions from the recorded archive.

B. BACKGROUND

Originally this research focused on other digital encoding schemes such as MPEG 1, MPEG 2, and MJPEG. Using these methods gave file sizes on the order of gigabytes for a feature length film (Klemets, 1994). Storing a reasonable collection of classes or lectures would require massive amounts of storage on expensive disks or in a tertiary storage system. Our such storage system is the Data Migration Facility (DMF) (also known as the "tape barn") at NPS. Due to the expense involved with using huge magnetic disks or off-site storage facilities, the DMF seemed to be the most economical alternative. Except for 1-2 minute delays during the mechanical movement of tapes during initial access, the retrieval process would require no special actions by remote users of the system.

The cost of DMF tapes (about $25 per 5 GB tape) reasonably satisfies the economical side of the problem. However, for sites that do not have mechanical tape stations this was not a feasible solution. Therefore, due to the difficulties managing file sizes created by these compression techniques, our focus turned to the use of the MBone

recording tools which simply save the packets of data that travel across the network. Here, the file sizes depend solely on the amount of bandwidth used in the transmission of each session. Lectures can be practically stored on LAN storage disks. Numerous NPS lectures comprising a video archive might still utilize the NPS DMF capabilities to augment ordinary server storage capacity.

C. BUILDING AN ARCHIVE

1. Recording

The video for this system is recorded using the MBone and the MBone VCR discussed in Chapter IV. The three simple steps involved in digitally recording an audio/video lecture (that already exists on video tape) are listed in Figure 5.1.

1. Create an MBone session with a ttl of 15 or less so that it does not go beyond the local network.
2. Begin playing the video tape to be recorded as the input to the MBone session.
3. Record the session on a separate workstation using the MBone VCR.

Figure 5.1 Simplified steps for digitally recording a video tape session using the MBone VCR

The session files are deposited directly to proper storage area and are ready to be played after competion. Appendix C provides a detailed explanation of the basic functions of the MBone VCR. Copyright permissions are not necessary for our current efforts since all sessions are in the public domain. This remains an important consideration in future work.

2. Storage Space

When considering the storage issues that apply to the MBone archive, the author had two main areas of concern. The most prominent question was how much digital storage a large archive might use. The second question was what type of storage media best supports web-based access to the archive.

The amount of digital storage space required for a recording is dependent on the amount of bandwidth used during the original session broadcast. The MBone has a maximum global capacity of 500 Kbps (at the time of this writing), but the standard transmission levels used for most sessions is 128 Kbps for video and 64 Kbps for audio. We assume that recording each session once (at a frame rate suitable for either local or global playback) is a practical solution. Using these numbers we arrive at a transmission that uses approximately 200 Kbps (a conservatively high estimate). Since the ultimate goal is to use this technology for a lecture-style digital classroom we will assume that each session will be a 50-minute lecture. Estimated digital storage requirements are shown in Figure 5.2.

200 Kbps stream * 8 bits/Byte = 25 KBps per second

25 KBps * 60 seconds/minute = 1500 KB/minute

1500 KB/minute = 1.5 MB/minute

1.5 MB/minute * 50 minutes/lecture = 75 MB/lecture, or

1.5 MB/minute * 60 minutes/hour = 90 MB/hour

Figure 5.2 Estimated digital storage requirements.

Therefore, with a 50 minute lecture, we expect to use 75 MBytes of space. Using these figures and assuming that each academic-quarter course will have about 30 lectures, a typical course might use an approximate total of 2.25 GB of storage space. These numbers are significantly smaller than the estimates established at the beginning of this research using MPEG compression and previous MBone tools. Recent improvements in the compression techniques used in the audio and video tools have further decreased the required bandwidth while at the same time improving frame rate and image resolution by factors of 2-4 times. This translates into less space required to archive the desired MBone sessions with acceptable audio/video quality. Experimental results reported in Chapter VI indicate that a 30-lecture archive may require just under 2 GB.

The type of storage media to be used in this system was the second issue to be addressed. Several options were examined, including the use of the DMF at NPS, CD-ROM or standard magnetic disk storage. This problem has been greatly simplified by the increasing efficiency of the compression techniques used by the MBone tools. Since the compression of the video and audio has provided for large reductions in file sizes and brings them down to manageable levels, individuals might even be able to start recording and watching short sessions on their own smaller typical LANs.

In this project at NPS we purchased a 9 GB hard drive for primary storage and investigated using the DMF as backup storage space. CD-ROM has a capacity of 650 MB, which is another possibility for storing the MBone sessions. Using a CD-ROM drive with a data transfer capacity of up to 600 KBps will allow distribution of the recorded lecture series or conferences to those hosts or networks that have slow outside

connections. CD-ROM may also be useful if the MBone VCR application is ported to the realm of the PC. Then even individuals with no network connection at all will be able to benefit from the content of the MBone. This is a promising area for future work.

In the end, the issue of what type of storage media to use must primarily be based on the type that is available and the purpose of the recordings at the site that is establishing an archive. Our site uses the 9 GB hard drive accessed via a standard UNIX-based Network File System (NFS) as primary store and the DMF as a backup facility.

3. File Naming Conventions

MBone VCR automatically generates a set of control files for each session recording. The session is specified in a session file that is named according to the session name and appended with a .vcr extension. The `session_name.vcr` file contains a description of the session, the included media and all of the media parameters in plain ASCII format. Along with the session file, VCR generates two other files per media in the same directory. The filenames for these files are also automatically generated out of the session filename, the media protocol and the media number. The first is a data file that ends in .rec (e.g. `session_name.rec`) that contains the raw data placed into the file as it is received from the network. The second is an index file that ends in .idx (e.g. `session_name.idx`) that contains one fixed-length header per data packet. This RTP header holds a mapped time stamp generated from information of the data time stamp, index information, channel information (e.g. data/session port) and an offset to the corresponding data packet in the `session_name.rec` file (Holfelder, 1995).

For example, if a user records a session consisting of one RTP media (such as audio) and has a session name of "test" the list of files will be:

```
test.vcr
test_rtp_1.idx
test_rtp_1.rec
```

Recording a session using a second RTP media (such as video) adds the following files:

```
test_rtp_2.idx
test_rtp_2.rec
```

The MBone VCR appends _rtp_1 for the first media and _rtp_2 for the second media. This simply to identifies the two types of media (e.g. audio_rtp_1 or video_rtp_2). It has nothing to do with the version of the RTP that is used. All media are recorded using RTPv2.

The author has chosen a simple session file naming convention that indicates the content and date of each lecture. An example set of all data and index file names that goes with a single Hamming Lecture session using audio and video is as follows.

```
Hamming_1_Apr95.vcr
Hamming_1_Apr95_rtp_1.idx
Hamming_1_Apr95_rtp_1.rec
Hamming_1_Apr95_rtp_2.idx
Hamming_1_Apr95_rtp_2.rec
```

This set of files is for the first lecture in the series of Hamming lectures. Care has been taken to ensure that when the sessions involve a series of lectures or conference meetings that the files are listed in the proper order. Here, the reader can see that the first lecture in the series will be listed before the second (Hamming_2_Apr95) all of the way through the 30th lecture.

The limitation of file name lengths that is imposed by DOS PCS was not taken into consideration with this naming scheme since (up to this point in time) the VCR is not supported by any PC systems. We expect that long self-descriptive filenames under UNIX can be mapped to 8-character filenames for DOS or CD-ROM storage with minimal difficulty.

D. ACCESS METHODS

Making the playback simple enough for MBone beginners is one of the top goals of this project. At this time the easiest technology to use is the World Wide Web. The web browsers available today have a highly simplified point and click interface, easily mastered by millions of users, and most web servers support common gateway interface (CGI) programming (Herrmann, 1996). Using the MBone VCR, CGI scripting, and file transfer protocol (ftp) the author has implemented two different methods for retrieving the recorded MBone sessions.

1. Web Page / CGI

This method uses a CGI script written in the *perl* language (available in Appendix B) that identifies the files to be played from a web page selection made by the user. The script then launches MBone VCR. The script response that the user sees provides directions that the user needs to properly launch the MBone tools on a local workstation. This is similar to the approach demonstrated by Anders Klemets in the Media on Demand System for WWW (Klemets, 1994). The uniform resource locator (URL) for this page is *http://www.it.kth.se/~klemets/vatplay.html*

This method of direct retrieval via the MBone will most likely be used by larger sites that have high-speed LANs (e.g. Ethernet or better) and high-speed connections (e.g. T-1, 1.5 Mbps) to the Internet. The bandwidth that is required here is the same as that which is required to watch MBone sessions live.

Through the use of the web page the user will have several choices for playback provided by the CGI script combo-form. User choices include what session is to be played, what media the user wants to receive (i.e. audio and video, only audio, or only video), what time-to-live (ttl) is to be used (default is local ttl=15), and what time the playback is to start (the default is immediately). Once the form is submitted by the user the server responds with a message that confirms the user's choices and tells the user what needs to be entered on the local host's command line to watch the playing session. Since the total MBone bandwidth is limited to 500 Kbps, only one user at a time will be allowed to play a global session. Users that come in after the session has started will be given a message similar to the first telling them what session is currently playing and what tools to launch in order to watch it. Important future work includes automating the local launch of the MBone tools, perhaps by using Java applets.

2. FTP

The ftp method uses a simple web page generated from a listing of compressed .tar files that include all files applicable to a particular session recording. The user selects a compressed .tar file and transfers that file to his location. Once the file has been transferred, the user uncompresses and expands the set of files and manually launches the MBone VCR. The user then chooses the set of files to be played by the VCR and watches

the session on his local network. In this case the scope of the new multicast session does not need to go beyond the user's local network.

This method will be used most often when the receiving network does not have an outside connection with suitable bandwidth to receive a live MBone transmission, but can support the tools either on a single workstation or on the local network. Smaller commands and geographically remote sites that do not have good telephone company support are perfect candidates for using this method. In this way, sites that cannot view multicast MBone content will now be able to see what they have been missing.

Figure 5.3 shows the UNIX command line entries required to tar/compress the MBone VCR session files. Once the files are compressed they can be transferred to the archive storage facility for retrieval. Figure 5.4 shows the entries that uncompress and untar the files.

Command	Description
`tar -cvf session_title.tar session_ title.vcr`	Creates the .tar file and adds the .vcr file to it
`tar -rvf session_title.tar session_ title_rtp_1.idx`	Adds first .idx file to .tar file
`tar -rvf session_title.tar session_title_rtp_1.rec`	Adds first .rec file to .tar file
`tar -rvf session_title.tar session_title_rtp_2.idx`	Adds second .idx file to .tar file
`tar -rvf session_title.tar session_title_rtp_2.rec`	Adds second .rec file to .tar file
`gzip session_title.tar`	Compresses the .tar file

Figure 5.3 UNIX command line entries to tar/gzip session files

Command	Description
`gunzip session_title.tar.gz`	Uncompresses the .tar file
`tar -xvf session_title.tar`	Extracts the five files from the .tar file

Figure 5.4 UNIX command line entries to untar/gunzip session files

E. BANDWIDTH REQUIREMENTS

The definition of bandwidth is the capacity of a communications connection to transmit data. Bandwidth can be dedicated to one user or shared among many users. In the case of the MBone, the maximum agreed bandwidth shared globally is 500 Kbps. This limitation is on a global scale, so this only limits the number of active world-wide sessions that can be played at any one time. Since the standard transmission levels of any MBone session are decreasing due to improved compression in the tools, several sessions (typically 2 or 3) can coexist using the limited capacity.

This MBone-on-demand system is set up to play only one global session at a time so as not to usurp the bandwidth available for the entire MBone community. Nevertheless, the number of local broadcasts is limited only by the campus LAN/backbone capacity. At NPS, we will limit that to two concurrent local MBone VCR playback sessions. Two session (400Kbps) easily fits into the 10 Mbps Ethernet/100 Mbps FDDI MBone on campus. Finally, the number of simultaneous ftp transfers is not constrained. The actual duration of those transfers depends on the current load on the network.

F. SUMMARY

This chapter reviews the reasons behind the focus of this thesis. It goes on to outline the major issues pertinent to building an MBone archive and describes the methods used to access such an archive. General considerations regarding bandwidth used for transmitting the contents of the recorded MBone sessions are presented. Appendix B shows the *html* and cgi scripts used to establish Web access to the video archive.

VI. EXPERIMENTAL RESULTS

A. INTRODUCTION

This chapter provides an overview of the experiments that were performed using version 1.3a01 of the MBone VCR. It then details the results of each attempt to use the MBone VCR to record and play MBone sessions. This is followed by an examination of the file sizes produced by recording conference session and the results of experiments performing each of the two retrieval methods discussed in chapter V.

B. OVERVIEW

The testing described in this chapter is accomplished using the MBone VCR's graphical user interface (GUI) and the MBone tools *sdr*, *vat* and *vic*. RTPv2, developed by the IETF AVT WG, is the protocol used by the transmitting tools and recorded by the MBone VCR. A software bug prevented our recording using *rat* with PCM redundancy enabled. This will be our preferred audio encoding due to significantly improved audio performance in the presence of network congestion and packet loss.

Since the MBone tools are used regularly and have been proven to work, the testing focuses on the addition of the MBone VCR to MBone process. The author had six goals (listed in Figure 6.1) when conducting the MBone VCR experiments, all intended to evaluate the effectiveness of this new combination of software tools.

Each initial recording experiment consisted of loading the audio and video session into the VCR interface and recording for five minutes.

♦Broadcasting and recording on the same workstation

♦Recording between workstations

♦Recording transmissions from another network

♦Playing and watching on the same workstation

♦Playing between workstations

♦Playing across networks

Figure 6.1 Experimental Test Goals

The binary distributions for all of the software application tools (*sdr*, *vic*, *vat*, *rat*, MBone VCR) are each downloaded from one of the many ftp sites that provide the MBone tools. The Multimedia Conferencing Applications Archive, supported by UK MICE National Support Center (Wood, 1996) is the most comprehensive of those sites. Appendix C gives the instructions for downloading and installing the proper tools as well as operating the MBone VCR.

C. RECORDING A SESSION

The first step in our testing the effectiveness of the MBone VCR is recording an MBone session. If the MBone session is broadcast using *sd* the MBone VCR can load it directly. If *sdr* is used, a corresponding new session must be created using the "create new session" function under the VCR session menu. The multicast addresses and port numbers (advertised by *sdr*) must be entered manually (this feature will be added in a future VCR version). Once the session is loaded into the VCR, a deposit directory is

selected and recording has been enabled on the user's workstation, recording begins by simply clicking on the MBone VCR record button.

The MBone VCR waits for the first packets of data to arrive via the multicast address/port and begins recording. In a separate UNIX shell listing, the files in the target directory using the UNIX command `ls-la` shows the set of files that is created and shows that the file size as data is being collected in those files. This process is followed for all three of the recording experiments with much the same result. The origin of the data did not affect the VCR in any adverse way. In all cases the same set of files is created and the files increased in size as the recording time increased. For all experiments we used default bandwidth settings for *vat* PCM audio (64 Kbps) and *vic* H.261 video (128 Kbps).

The file sizes differ slightly with the different transmission origins but that can be attributed to the packet loss increases as the distance between transmitting workstation and receiving workstation increases. File sizes are noticeably smaller when the receiving network has a heavy load. This can also be attributed to the quality of signal received by the recording workstation. On average, the total amount of data collected in the five files for each session is approximately 1.3 MB per minute (just under the capacity of a 3.5" floppy diskette) or 6.5 MB per five minute period. Of interest is the fact that this rate corresponds to approximately 78 MB/hour, comfortably less than the 90 MB/hour storage rate predicted in Figure 5.2.

D. PLAYING A RECORDED SESSION

The next step in evaluating the MBone VCR is to play the recorded sessions. Playing and watching the recorded sessions is accomplished in one of three ways. The

first is to create a new MBone session with *sd* or *sdr*. Then copy the advertised multicast addresses and port numbers and edit the recorded session's media to match the new session (MBone VCR provides an easy way to accomplish this). Pressing the play button on the GUI then plays the session. This test was performed on all of the recordings mentioned in Section 1 above.

Feedback from individuals across the country who watched a global rebroadcast of a session reported that the video was clear but the audio was not present in the transmission. Remote participants watched the session by launching *vic* and *vat* from *sdr*. When launched in this manner, *vat* is started with the -r synchronization switch. The author experienced the same symptoms on the local network and on the same workstation that was playing the session, but fixed the lack of audio by launching *vat* from the UNIX command line without the -r switch. A command similar to the following was used:

```
vat -f pcm -t 127 -I 1 -C "Test Session" 224.2.230.15/65042
```

Without the -r, the audio portion of the session was heard clearly. This VCR bug has been reported and is expected to be fixed in the near future. No feedback was received from anyone outside of the local network once the audio problem was fixed locally. Further tests showed that this lengthy command line entry was not needed. Simply specifying the tool and the address/port numbers will allow the user to receive the signal. The actual command line entry needed is as follows:

```
vat 224.2.230.15/65042
```

The second technique of playing a recorded session is to create a new MBone session by manually setting the multicast addresses and port numbers to match those that

were used by the original transmission at the time of recording. Watching each of the three rebroadcasts using *sdr* to launch *vic* and *vat* provides the same results as above. As long as *vat* is launched from the command line without the -r synchronization switch, the audio is heard. Properly using the -r does not allow *vat* to receive the data being transmitted by the MBone VCR if the -r was not used to transmit the original signal. If the -r is used when transmitting the original recorded session, the audio will be heard with or without using the -r when receiving the signal transmitted by the MBone VCR. This confusing state of affairs will be much simpler when the bug is corrected.

The third technique of playing the recorded sessions is to simply load a session and click on the play button without creating a new session in *sdr*. The drawback here is that no advertisement of the playing session is sent out to the local or global MBone. However, if the session is launched locally or from a web page, the exact command line entries needed to watch the session with *vic* and *vat* are given before play begins. No global unadvertised multicasts have been originated using this method, in deference to MBone usage conventions (Macedonia, Brutzman, 1994). Locally the session can be watched as clearly as the original multicast. This third approach is not recommended for normal us and is only documented here for completeness.

E. RECORDING A COMPLETE LECTURE

The tests up to this point had shown that the MBone VCR can be used for short periods without failing. The next step was to record an entire lecture or conference to examine the performance for an extended period of time (1-2 hours). The session that was chosen was the video tape of the August 1996 SIGGRAPH Virtual Reality Modeling

Language (VRML) Special Interest Group (SIG). The video tape was multicast from one workstation using *vat* and *vic* and recorded on another using the MBone VCR. Again the default bandwidth for audio and video were used and the file sizes increased as the recording time increased. The tape was slightly longer than two hours and the five files created by the MBone VCR totaled slightly less than 156 MB, approximately 75 MB per hour of recording. This number is of interest since it shows that and entire lecture series (30+ lectures) might fit into less than 2 GB of storage space.

F. WEB PAGE/CGI SCRIPT LAUNCH

After testing the MBone VCR, the next step was to test the combo-form and *perl* scripts that let a user select an MBone session from the recordings and automatically start the playback of the selected session through the use of a macro command file generated by the *perl* script. The *perl* scripts and the HTML that generates the combo-form can be found in Appendix B. The use of the macro command file is explained in detail in Appendix C. The URL for the Web page is

http://www.stl.nps.navy.mil/~iirg/metiddy/player_frames.html

The Web page interface was tested by selecting a session from the drop-down menu, selecting a media, giving a playback start time, and giving a session ttl. The submit button was then clicked and the results page correctly showed the information that had been entered into the form. The macro command file was opened in a text editor to see if the proper commands had been entered into it. All of the appropriate commands to launch the MBone VCR had been correctly written to the file.

Next the submit button generated by the first script and the command file itself were tested. The Web page returned and error indicating that the script was malfunctioning. The syntax of the script was checked and returned no errors. The script was then run from the UNIX command line. Doing this showed that the -c option in the MBone VCR (which allows the application to be started from the command line using a macro command file) was not functioning properly. The MBone VCR was started but the macro command file was not read. However, using the "macro" menu option in the MBone VCR interface to test the command file showed that it did successfully load and play the proper recorded session. Once the -c option in the MBone VCR is functional, the automatic playback system is also expected to function. This software bug has also been reported.

G. FTP RETRIEVAL

The final step in the testing process was to exercise the ftp retrieval method in order to ensure the data in the .tar.gz file was not corrupted in the tar/compress uncompress/untar process. The file was first transferred from the DMF to the local network. Next the commands listed in Figure 5.4 were used to uncompress and untar the files. The session was then loaded into the MBone VCR and played over the local network. The session was watched on the workstation that was running MBone VCR and another workstation on the same network. Both receiving workstations used *vat* and *vic* launched from the command line. The session was viewed as clearly as before it was archived on the DMF. The DMF archive location is on `sirius.cc.nps.navy.mil` in directory `/h/d1/iirg`.

H. EVALUATION OF RESULTS

All of the MBone sessions were recorded in three different ways and the three methods of playback were attempted on each of the three recorded sessions. The testing was performed using the VCR's GUI and a combination of *sdr*-launched and command-line-launched MBone tools.

In all experimental cases the default transmission rates on the audio and video provided a clear reproduction of the original audio/video session. Using the default video quality level of 10 during recording seemed to strike the best balance between quality of picture and movement during playback. Participants were able to read any slides that the instructor or lecturer used and the frame rate was sufficient for meaningful expression of gestures. Facial expressions can sometimes be discerned usefully at this frame rate. No experiments were conducted using the MBone whiteboard (*wb*) tool to transmit slides since the MBone VCR does not yet support *wb*.

The results of the audio/video testing are satisfactory and demonstrate successful recording and playback. These various combinations of tests successfully demonstrated all of the software test goals listed in Figure 6.1.

I. SUMMARY

This chapter provides the results of experimental testing performed using the MBone VCR. Each experiment is discussed as it relates to the six goals outlined in the overview of the experimental process. The chapter then explains the results attained when an entire conference was recorded and the two retrieval methods were tested. The chapter ends with an evaluation of the experimental results.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. RESEARCH CONCLUSIONS

The MBone VCR has been successfully implemented on a local basis around the NPS campus. Limited success was achieved on a larger scale, however the level of success cannot be measured due to the minimal feedback from remote sites. It is easy to see that the MBone VCR can help enhance the capabilities of the world-wide multimedia teleconference and distance education already taking place on the Multicast Backbone (Holfelder, 1995). Further testing and development is needed to better quantify these conclusions.

The video quality of the recordings is not yet clear enough for feature films, but sacrificing a small amount of quality provides for manageable file sizes. This is extremely important when looking at the distance learning concept from an economic standpoint. At this point in the use of the MBone VCR, the quality of the recording is only as good as the original MBone broadcast. As the MBone tools continue to improve so will the quality of the recorded sessions. As a result of this research, the realm of distance education is one step closer to being truly independent of time and geographic location.

B. RECOMMENDATIONS FOR FUTURE WORK

The technical aspects of research such as this are only part of the story when the overall results can affect people's lives. Once the technology has been proven to work, the next step is to look at how it can be integrated into daily life. The whole purpose of the concept of distance education is to help people learn. Therefore, research on the

human aspect of distance education needs to include a look at how the content of a class or conference is best tailored for effective distance delivery. Correcting the few remaining bugs in the technical results of this thesis will enable such research.

While the tests on the MBone VCR were successful, there are several areas that could be improved in future versions of the application. Since the MBone tools are already available for most PC platforms, the next logical step for the VCR would be to port the program to PC operating systems. This would allow even the smallest networks that may have high-speed internal connections to download the recorded sessions and play them locally (assuming their outside network connections do not support higher speeds). This can also open the possibility of putting the recorded sessions on CD-ROM and allowing individuals who may have no network connection at all to watch the sessions on their own home systems. The numbers of people able to participate in distance education programs then begins to grow exponentially.

Another needed improvement to the MBone VCR is compatibility with the redundant audio encodings used in *rat*. The use of FEC provides notable performance enhancement during periods of poor network performance without increasing the required bandwidth. We recommend that video archives be recorded using redundancy.

Several improvements can also be made to the MBone-on-Demand system at NPS. Currently the system has no way of restricting the number of sessions playing at one time. One piece of future work might be to complete a lockfile system limiting the number of global multicast sessions so the system does not overrun the whole MBone. The Hamming lecture series that was multicast for an entire quarter is ready to be digitally

stored using the redundant encoding in *rat* (when it is made compatible with MBone VCR) and *vic*. Other additions to the system, such as getting permanently assigned multicast addresses and port numbers for a global MBone VCR channel will continue to make it easier to use and more readily accessible.

As with any new software tool, more testing is needed. Playing and recording remotely across different networks and different platforms has only begun. Now that the VCR tool is here and useable, it can only get better and become more beneficial. Important additional work includes automatic local launch of appropriate MBone tools, perhaps using Java applets.

Finally, as seen in "The Digital Library Phenomenon: Opportunities and Implications for the Naval Service," the Naval service can benefit tremendously from meeting non-tactical, day-to-day information needs (Norris, West, 1996). The digital library is a concept that is catching on quickly throughout today's educational infrastructure. As that concept grows into actual systems, one goal for the educators involved can be to incorporate distance educational systems like the MBone-on-Demand system discussed in this thesis into the overall infrastructure. We look forward to the day when the use of tools such as the MBone VCR is widespread and easy.

APPENDIX A: GLOSSARY

ACM - Association for Computing Machinery: A large and long-standing professional organization dedicated to most of the important issues related to computers.

Anonymous ftp: A log-on convention used by Internet that lets a user retrieve files from a file transfer protocol (ftp) server, even though the user may not have an account on that server.

ANSI - American National Standards Institute: The primary standards organization in the U.S.

ATM - Asynchronous Transfer Mode: International standard for cell relay in which multiple service types (such as voice, video, or data) are conveyed in fixed-length (53-byte) cells. Fixed-length cells allow cell switching to occur in hardware, thereby reducing transit delays. ATM is designed to take advantage of high-speed transmission media such as fiber optic cable.

Compression: The art/science of reducing the number of bits required to store and/or transmit digital media. Predominant schemes include MPEG 1, MPEG 2, motion JPEG. MPEG performs intra-frame compression as well as inter-frame (or differences from frame-to-frame) compression. JPEG, which is predominantly a still-image compression scheme, performs only intra-frame compression.

Digitization: The art/science of converting analog video, images, or audio into digital format (i.e., 1s and 0s)

Hypertext Markup Language - HTML: The source language for making World Wide Web 2D hypermedia pages. HTML not only formats a Web page, but also provides for links to other Web pages or documents.

Hypertext Transfer Protocol - HTTP: The Internet protocol that enables the World Wide Web. This is the protocol designed for serving HTML documents. It is a client/server-based protocol.

IEEE - Institute of Electrical and Electronics Engineers: Professional organization whose activities include the development of communications and network standards. IEEE LAN standards are the predominant LAN standards today.

IETF - Internet Engineering Task Force: Task force consisting of over 80 working groups responsible for developing Internet standards.

Internet: Term used to refer to the largest global internetwork, connecting tens of thousands of networks worldwide and having a "culture" that focuses on research and standardization based on real-life use. Many leading-edge network technologies come from the Internet community. The Internet evolved in part from ARPANET. At one time, called the DARPA Internet. Not to be confused with the generic term internet.

internet: Short for internetwork. While an internet is a network that uses the same technology (such as TCP/IP), the term "internet" is usually used to refer to a collection of such networks interconnected with routers. Not to be confused with the global Internet.

IP - Internet Protocol: Network layer protocol in the TCP/IP stack offering a connectionless-routed internetwork service. IP provides features for addressing, type-of-service specification, fragmentation and reassembly, and security.

IP address: 32-bit address IPv4 (or 128-bit address in IPV6) assigned to hosts using TCP/IP. An IPv4 address belongs to one of five classes (A, B, C, D, or E) and is written as 4 octets separated with periods (dotted decimal format). Each address consists of a network number, an optional subnetwork number, and a host number. The network and subnetwork numbers together are used for routing, while the host number is used to address an individual host within the network or subnetwork. A subnet mask is used to extract network and subnetwork information from the IP address. Also called an Internet address or host address.

IP multicast: Routing technique that allows IP traffic to be propagated from one source to many destinations or from many sources to many destinations. Rather than sending duplicate packets to each destination, each packet is sent to a multicast group identified by a single IP destination group address. Packet replication occurs at routers in a classical router-based network. Multicast traffic uses class D IP addresses.

LAN - Local-Area Network: High-speed, low-error data network covering a relatively small geographic area (up to a few thousand meters). LANs connect workstations, peripherals, terminals, and other devices in a single building or other geographically limited area. LAN standards specify cabling and signaling at the physical and data link layers of the OSI model. Ethernet, FDDI, and Token Ring are widely used LAN technologies.

MPEG 1 - Motion Picture Experts Group: Compressed digital video/audio stream. MPEG 1 is 1/4 broadcast quality which translates to 352x240 pixels. Typically compressed at 1.5 Mbps. Pronounced "m-peg".

MPEG 2 - Motion Picture Experts Group: Compressed digital video/audio stream. MPEG 2 is broadcast quality and translates to 704x480 pixels at 30 frames per (fps)

second in North America and 704x576 fps at 25 fps in Europe. Currently a draft standard. Typically compressed at higher than 5 Mbps and meant for higher quality/broadcast uses.

Multicast Backbone (MBone): A virtual network that provides many-to-many global network delivery services for applications such as videoconferencing and audio where several hosts need to communicate simultaneously. Provides multicast connectivity between LANs across the Internet.

Multicasting: The ability of an application to send a single message to the network and have it delivered to multiple recipients at possibly different locations.

PCM - Pulse-Code Modulation: Transmission of analog information in digital form through sampling and encoding the samples with a fixed number of bits. Refers to a commonly used audio encoding algorithm.

RFC - Request For Comments: Document series used as the primary means for communicating information about the Internet. Most RFCs document protocol specifications (e.g. telnet and ftp). A complete index of RFCs is available at *http://dis.internic.net/rfc/*

Rlogin - remote login: Terminal emulation program (similar to telnet) offered in most UNIX implementations. Passwords are not encrypted during transmission.

TCP - Transmission Control Protocol: Connection-oriented transport layer protocol that provides reliable full-duplex data transmission. TCP is part of the TCP/IP protocol suite at the same level as best-effort UDP.

TCP/IP - Transmission Control Protocol/Internet Protocol: Common name for the suite of protocols developed by the U.S. DoD in the 1970s to support the construction of world-wide internetworks. Common protocol suite used throughout the Internet.

telnet: Standard terminal emulation protocol in the TCP/IP protocol stack. telnet is used for remote terminal connection, enabling users to log in to remote systems and use resources as if they were connected to a local system. Passwords are not encrypted during transmission.

Time to Live (ttl): A counter used to limit multicast packet lifetimes. A threshold that a multicast datagram needs to be forwarded onto a given tunnel.

Unicasting: One host exchanging packets with another single specific host.

URL - Uniform Resource Locator: Standardized addressing scheme for identifying hypertext documents and other services using a Web browser.

Video Teleconferencing (VTC): A two-way electronic form of communication that permits two or more people in different locations to engage in face-to-face audio and visual communication. Meetings, seminars, and conferences can be conducted as if all participants are in the same room.

Video Teletraining: The use of point-to-point or multi-point teleconferencing to provide interactive remote site training.

WAN - Wide-Area Network: Data communications network that serves users across a broad geographic area, often uses transmission services provided by common carriers.

WWW (Web) - World Wide Web: Large network of Internet servers providing hypertext and other services to terminals running client applications such as a Web browser. More generally, all information resources available via the Internet.

Web browser: Hypertext client application (such as Mosaic or Netscape) used to access hypertext documents and other services located on innumerable remote servers throughout the Web and the Internet. Text-based, graphical user interface (GUI) and 3D graphics browsers using the Virtual Reality Modeling Language (VRML) are also available.

APPENDIX B: HTML FOR MBONE PLAYER PAGE AND CGI/PERL SESSION RETRIEVAL SCRIPTS

HTML for the MBone Player Page

This section is the listing of the HTML that produces the combo-form. This HTML provides the user interface on the NPS MBone player page. The URL of the Web page is *http://www.stl.nps.navy.mil/~iirg/tiddy/player_frames.html*

```
<html>
<head>
<title> NPS MBone Player Page</title>
</head>

<h2 align=center>NPS <i>MBone </i>Playback</h2>

<center><p>
<form method=post action="cgi-bin/vcr_input.cgi"
target="results_window">

<table border=10 cellspacing=0 cellpadding=5>
<caption align=top></caption>

<tr>
<th align=center><font size = 4>User Information</font size = 4></th>
</tr>

<tr>
<td align=center>
<br><input type=text name=name size=12 value="UserName?"></p></center>
</td>
</tr>

<tr>
<th align=center><font size = 5>Select a Session</font size = 5</th>
</tr>

<tr>
<td>
Hamming Lectures
<select name=session align=right>
<option value="1" selected> 1-- DD/MM/YY
<option value="2"> 2-- DD/MM/YY
<option value="3"> 3-- DD/MM/YY
<option value="4"> 4-- DD/MM/YY
<option value="5"> 5-- DD/MM/YY
<option value="6"> 6-- DD/MM/YY
<option value="7"> 7-- DD/MM/YY
<option value="8"> 8-- DD/MM/YY
<option value="9"> 9-- DD/MM/YY
<option value="10"> 10-- DD/MM/YY
<option value="11"> 11-- DD/MM/YY
<option value="12"> 12-- DD/MM/YY
<option value="13"> 13-- DD/MM/YY
<option value="14"> 14-- DD/MM/YY
```

```
<option value="15"> 15-- DD/MM/YY
<option value="16"> 16-- DD/MM/YY
<option value="17"> 17-- DD/MM/YY
<option value="18"> 18-- DD/MM/YY
<option value="19"> 19-- DD/MM/YY
<option value="20"> 20-- DD/MM/YY
<option value="21"> 21-- DD/MM/YY
<option value="22"> 22-- DD/MM/YY
<option value="23"> 23-- DD/MM/YY
<option value="24"> 24-- DD/MM/YY
<option value="25"> 25-- DD/MM/YY
<option value="26"> 26-- DD/MM/YY
<option value="27"> 27-- DD/MM/YY
<option value="28"> 28-- DD/MM/YY
<option value="29"> 29-- DD/MM/YY
<option value="30"> 30-- DD/MM/YY
<option value="31"> SIGGRAPH VRML SIG
</select>
</td>
</tr>

<tr>
<td>
<center>Media Type   
<select name=media>
<option selected value="audio_and_video">Audio and Video
<option value="audio">Audio Only
<option value="video">Video Only
</select></center>
</td>
</tr>

<tr>
<th align=center><input type="submit" value="Submit Playback
Information"> </th>
<tr>
<th align=center><input type="reset" value="Reset Defaults"></th>

<tr>
<th> </th>
</tr>

<tr>
<th align=center><font size = 5> Advanced Options</font size = 5></th>
</tr>

<tr>
<td align=center>
<align=left><p>Playback Start time (PDT)
<input type=text name=start_time size=17 value="HH:MM:SS MM/DD/YY"><br>
If you need help, here's a
      <a href="http://poisson.ecse.rpi.edu/cgi-bin/tzconvert"
target="_top">
      timezone converter</a>.
</td>
</tr>

<tr>
```

```
<td align=right>
<center><p>Multicast time-to-live (ttl) scope
<br><select name=ttl align=right>
<option value="1">1: local-area network (LAN)
<option value="15" selected>15: NPS
campus <option value="32">31: Monterey Bay (approx.)
<option value="128">127:World-wide MBone
<option value="171">171: Global audio MBone
</select>

</td>
</tr>

<tr><td><center>
You can also download the entire series as .tar files by going to the
Lecture Series
<a href="http://www.stl.nps.navy.mil/~iirg/tiddy/hamming_archive/"
target="results_window">
FTP Archive</a>.</center>
</tr>


</table>

</form></center>

<p>
<p>
<hr>
Last update:  12 September 1996
</body>
</html>
```

VCR Input Script

```
#!/usr/local/bin/perl
#
#vcr_input
#
# This script takes input from a combination form
# echos that information on a second Web page and
# writes the information to a macro command
# file that will be used by the VCR to play the
# chosen MBone session.
#
# Michael Tiddy <metiddy@nps.navy.mil>
# 17 Sept. 1996
# http://www.stl.nps.navy.mil/~iirg/tiddy/vcr_input.cgi
#
# References:
#
# Herrmann, Eric, Teach Yourself CGI Programming with
# Perl in a Week, first Edition, Sams.net Publishing, 1996.
#
# Tiddy, Michael E., Internetworking:  Economical Storage
# and retrieval of Digital Audio and Video for Distance
# Learning, Master's Thesis, Naval Postgraduate
# School, Monterey, California, September 1996.
#
# Wall, Larry, and Schwartz, Randal L.,
# Programming Perl, O'Reilly & Associates, Inc., 1991.
#
#
#
#

push(@INC, "/cgi-bin");
require("cgi-lib.pl");

require("ctime.pl");

&ReadParse(*input);

#Get the User_name
$user_name = $input{'name'};

$mydate = `date`;

if ($input{'start_time'} eq "HH:MM:SS MM/DD/YY") {
      $start = "$mydate";
      }
   else {
     $start = $input{'start_time'};
      }


#Determine the lecture chosen

if ($input{'session'} eq "1") {
   $session_name = "Hamming1_MM/YY";
   }
```

```
elsif ($input{'session'} eq "2") {
   $session_name = "Hamming2_MM/YY";
   }
elsif ($input{'session'} eq "3") {
   $session_name = "Hamming3_MM/YY";
   }
elsif ($input{'session'} eq "4") {
   $session_name = "Hamming4_MM/YY";
   }
elsif ($input{'session'} eq "5") {
   $session_name = "Hamming5_MM/YY";
   }
elsif ($input{'session'} eq "6") {
   $session_name = "Hamming6_MM/YY";
   }
elsif ($input{'session'} eq "7") {
   $session_name = "Hamming7_MM/YY";
   }
elsif ($input{'session'} eq "8") {
   $session_name = "Hamming8_MM/YY";
   }
elsif ($input{'session'} eq "9") {
   $session_name = "Hamming9_MM/YY";
   }
elsif ($input{'session'} eq "10") {
   $session_name = "Hamming10_MM/YY";
   }
elsif ($input{'session'} eq "11") {
   $session_name = "Hamming11_MM/YY";
   }
elsif ($input{'session'} eq "12") {
   $session_name = "Hamming12_MM/YY";
   }
elsif ($input{'session'} eq "13") {
   $session_name = "Hamming13_MM/YY";
   }
elsif ($input{'session'} eq "14") {
   $session_name = "Hamming14_MM/YY";
   }
elsif ($input{'session'} eq "15") {
   $session_name = "Hamming15_MM/YY";
   }
elsif ($input{'session'} eq "16") {
   $session_name = "Hamming16_MM/YY";
   }
elsif ($input{'session'} eq "17") {
   $session_name = "Hamming17_MM/YY";
   }
elsif ($input{'session'} eq "18") {
   $session_name = "Hamming18_MM/YY";
   }
elsif ($input{'session'} eq "19") {
   $session_name = "Hamming19_MM/YY";
   }
elsif ($input{'session'} eq "20") {
   $session_name = "Hamming20_MM/YY";
   }
elsif ($input{'session'} eq "21") {
```

```
   $session_name = "Hamming21_MM/YY";
   }
elsif ($input{'session'} eq "22") {
   $session_name = "Hamming22_MM/YY";
   }
elsif ($input{'session'} eq "23") {
   $session_name = "Hamming23_MM/YY";
   }
elsif ($input{'session'} eq "24") {
   $session_name = "Hamming24_MM/YY";
   }
elsif ($input{'session'} eq "25") {
   $session_name = "Hamming25_MM/YY";
   }
elsif ($input{'session'} eq "26") {
   $session_name = "Hamming26_MM/YY";
   }
elsif ($input{'session'} eq "27") {
   $session_name = "Hamming27_MM/YY";
   }
elsif ($input{'session'} eq "28") {
   $session_name = "Hamming28_MM/YY";
   }
elsif ($input{'session'} eq "29") {
   $session_name = "Hamming29_MM/YY";
   }
elsif ($input{'session'} eq "30") {
   $session_name = "Hamming30_MM/YY";
   }
elsif ($input{'session'} eq "31") {
   $session_name = "SIGGRAPH_VRML_SIG";
   }

#get requested ttl from combo-form user input
$session_ttl = $input{'ttl'};

#get requested media types
$media_type = $input{'media'};
if ($input{'media'} eq "audio")
      {$tool1 = "vat 224.2.222.204\/29366 \&";
       $tool2 = "No video tool";
}
elsif ($input{'media'} eq "video")
      {$tool1 = "No audio tool";
       $tool2 = "vic 224.2.170.70\/65114 \&";
      }
elsif ($input{'media'} eq "audio_and_video")
      {$tool1 = "vat 224.2.222.204\/29366 \&";
       $tool2 = "vic 224.2.170.70\/65114 \&";
      }

print "Content-type: text/html\n\n";
print"<html>\n";
print"<head>\n";
print"<title> NPS MBone Player Page</title>\n";
print"</head>\n";
print"<body>\n";
```

```
print"<h2 align=center>NPS <i>MBone </i>Playback</h2>\n";
print"<center>\n";
print"<table border=5 cellspacing=0 cellpadding=5>\n";

print"<tr align=center>\n";
print"<td>\n";
      print"<h2>Hello $user_name.<br>\n";
      print"It is $mydate.<br>\n";
      print"This is your playback information!</h2>\n";
print"</tr>\n";

print"<tr align=left>\n";
print"<td>\n";
print"<ul>\n";
      print"<li>You have chosen the following
session:<br>$session_name<br>\n";
      print"<li>You have chosen $media_type as your media.<br>\n";
      print"<li>Your start time is $start PDT.<br>\n";
      print"<li>Your ttl is $session_ttl<br>\n";
print"</ul>\n";
print"</tr>\n";

print"<tr align=left>\n";
print"<td>\n";
      print"You need to use the following commands to start the proper
tool(s):<br>\n";
      print"<ul>\n";
      print"<li>$tool1 <br>\n";
      print"<li>$tool2 <br>\n";
      print"</ul>\n";
print"</table>\n";
print"</center>\n";
print"<br>\n";

print"<center>\n";
print"If all of the information above is correct,<br>\n";
print"press the button to launch the playback.<br>\n";
print"<form method=post action=\"vcr_start.cgi\">\n";
print"<tr>\n";
if ($input{'start_time'} eq "HH:MM:SS MM/DD/YY"){
      print"<th align=center><input type=\"submit\" value=\"Start
Playing Now\">\n";
      }
else {
      print"<th align=center><input type=\"submit\" value=\"Start
Playing at $start\">\n";
      }
print"</th>\n";
print"</form>\n";
print"</center>\n";
print"</body>\n";
print"</html>\n";

#open vcr macro file
open (CMD,">/usr/local/videoData4/play.cmd") || die "can't open $cmdfn:
$!\n";
```

```
# start playing at $start
if ($input{'start_time'} eq "HH:MM:SS MM/DD/YY"){
      print CMD "#play starts immediately, $start\n";
      }
else {
      print CMD "at $start\n";
      }
# load session
print CMD "load /usr/local/videoData4/$session_name.vcr\n";
#start playing
print CMD "play\n";
# play for 2.0 hours
print CMD "wait 02:00:00\n";
# stop playing
print CMD "stop\n";
# unload $session_name
print CMD "unload\n";
# quit vcr
print CMD "quit\n";
#close macro command file
close(CMD);

exit;
```

VCR Start Script

```
#!/usr/local/bin/perl
#
#vcr_input
#
# This script is triggered by the submit button created by
# the previous script.  The result of this script is the
# playing of the chosen MBone session.
#
#
# Michael Tiddy <metiddy@nps.navy.mil>
#
#
# 17 Sept. 1996
# http://www.stl.nps.navy.mil/~iirg/tiddy/vcr_input.cgi
#
# References:
#
# Herrmann, Eric, Teach Yourself CGI Programming with
# Perl in a Week, first Edition, Sams.net Publishing, 1996.
#
# Tiddy, Michael E., Internetworking:  Economical Storage
# and retrieval of Digital Audio and Video for Distance
# Learning, Master's Thesis, Naval Postgraduate
# School, Monterey, California, September 1996.
#
# Wall, Larry, and Schwartz, Randal L.,
# Programming Perl, O'Reilly & Associates, Inc., 1991.
#
#
#
# Make cgi interpreterstart looking for libraries and functions
# your own directory
push(@INC, "/cgi-bin");

require("cgi-lib.pl");

#set the path to the VCR executable file
$vcr = "/usr/local/bin/vcr";

#executes the VCR command with the -c option giving the path name to the
macro #command file
exec "$vcr -c /usr/local/videoData4/play.cmd &";
```

APPENDIX C: INSTRUCTIONS FOR BASIC OPERATION OF THE MBONE VCR

This user's guide has been created using much of the information provided by the creator of the MBone VCR in the postscript file that accompanies the actual program. It is designed to assist anyone that desires to use the MBone VCR to record or playback a multicast session. There are no instructions here for connecting to the MBone or using the MBone tools. Information on either of those topics can be found at *The MBone Information Web* available at *http://www.best.com/~prince/techinfo/mbone.html*

OVERVIEW OF THE MBONE VCR

A session recorded by VCR can consist of as many multicast channels as a user desires to record. During recording, the MBone VCR will synchronize these time-critical data streams based on information provided by protocols such as RTPv1 or RTPv2 (the Real Time Transport Protocol). The MBone VCR does not need to know which particular application originates a data stream or what the exact content of the data stream is; it suffices that the data stream conforms to one of the supported protocols.

To play back a recorded session, the MBone VCR sends the data out to the network, recovering the original timing and synchronization of all the media streams included in this session and using the same network protocols used by the applications from which the data was recorded. Therefore users run these application in order to watch and/or listen to the data played back by the MBone VCR.

The main MBone VCR window tries to imitate the look of a home vcr. The left area of the main window gives some status information about the loaded session whereas the right area provides a session clock and buttons to control the session.

GETTING THE TOOLS

The free MBone tools and the MBone VCR can all be retrieved using ftp from *ftp://ftp.ucs.ed.ac.uk*

The site contains a description as well as an index to the source and binaries for all of the available conferencing tools (Wood, 96). Once the tools have been transferred the user must unzip and use the tar -xvf function to install them on the local workstation or network. Each tool contains a README file help with any further installation requirements.

To use the MBone VCR you will also need TCL version 7.5 and TK version 4.1 installed in the directory tree above MBone VCR. If the user does not have root permission and cannot fully install TCL/TK, the user can set two environment variables via the command line or in .cshrc with entries resembling the following:

```
setenv TCL_LIBRARY ~/[master directory]
setenv TK_LIBRARY ~/[master directory]
```

The current versions of TCL and TK can be found at *ftp://ftp.smli.com/pub/tcl/*

USING THE MBONE VCR

Once fully installed, typing `vcr` at the shell prompt starts the VCR. Figure C.1

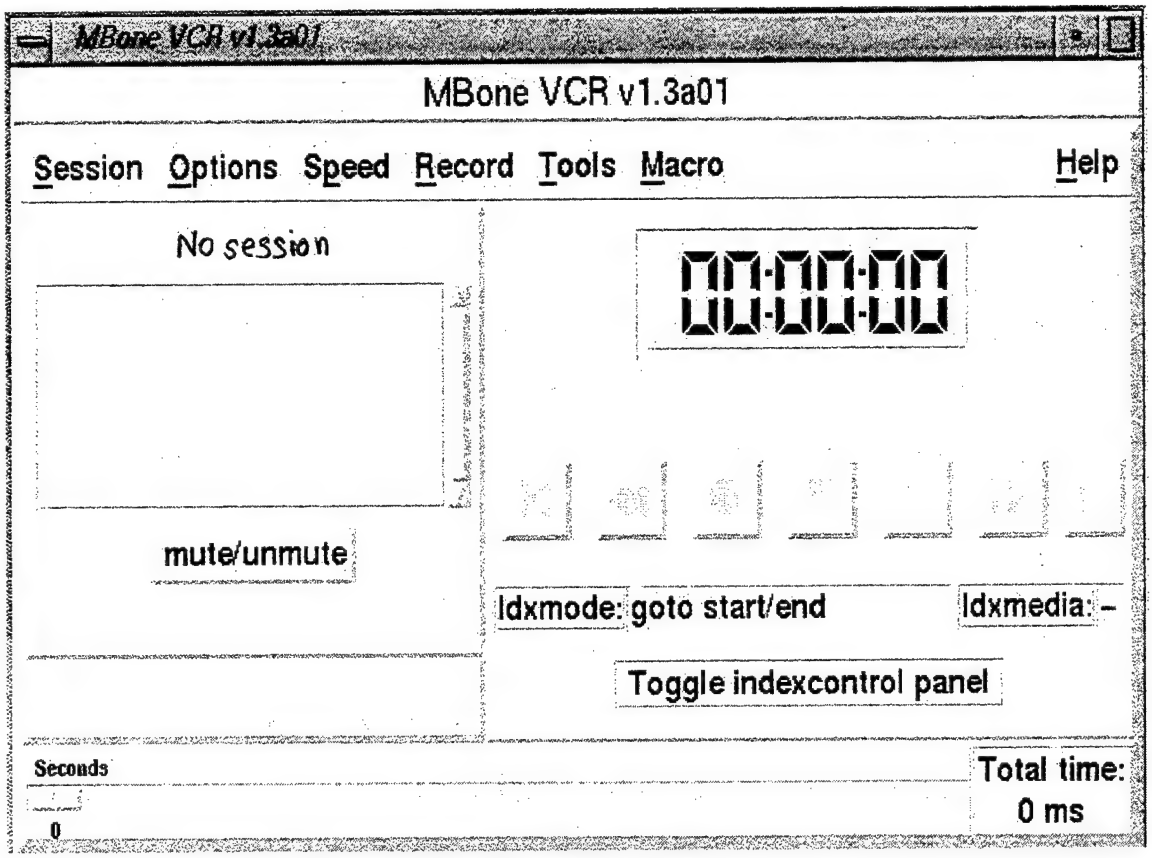

Figure C.1. MBone VCR User Interface

shows the user interface.

The following sections describe the basic functions available to the users of the MBone VCR.

OPEN A SESSION

If no session is loaded, "No session" is displayed in the status area of the VCR window and the media list (below) is empty. To open an existing session one can either use the "Open Session..." entry in the "Session" menu or double click on the "No Session" label. Change the pathname to the local MBone storage directory and select a session. Figure C.2 shows the "Open Session" window.

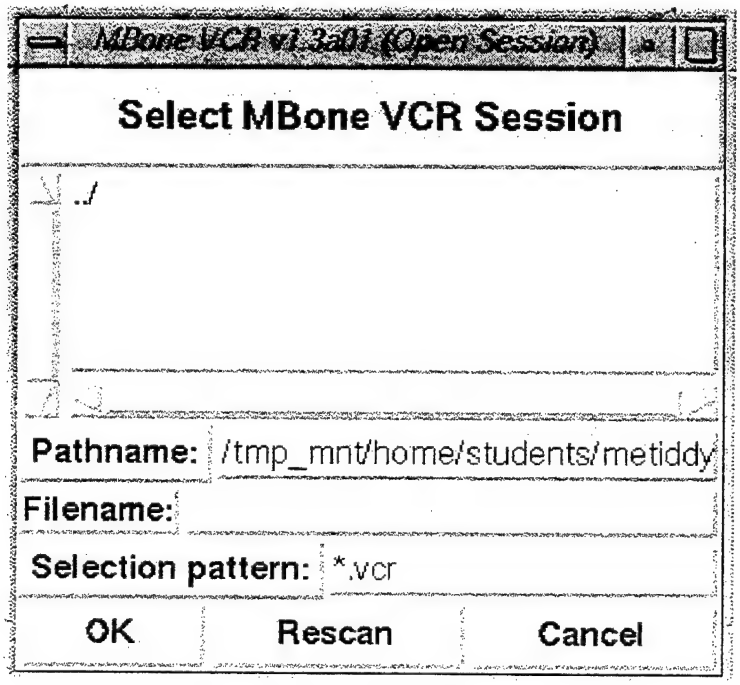

Figure C.2. Open Session

IMPORT A SESSION FROM THE SESSION DIRECTORY

This is probably the easiest way to get started. If you have *sd* running, it creates a file `.sd_cache` in your home directory (you might need to quit and restart sd in order to get an updated version of `.sd_cache`). The MBone VCR can read and interpret this file and create a VCR-session out of it. Just click on "Import SD Session" in the "Session" menu and choose from one of the sessions. Figure C.3 shows the "Open Session" window. VCR will ask you for a filename after you have chosen a session (it creates a default filename out of the session name so you might just want to select an appropriate directory). Click OK and you are ready to record this session. Since the sessions in *sd* often only include one media, you might need to edit the session to add more media from sd-sessions to your VCR-session (see below for more information). If you are using *sdr* you will have to manually create a new VCR session using the same address and port numbers as the *sdr* session you want to record.

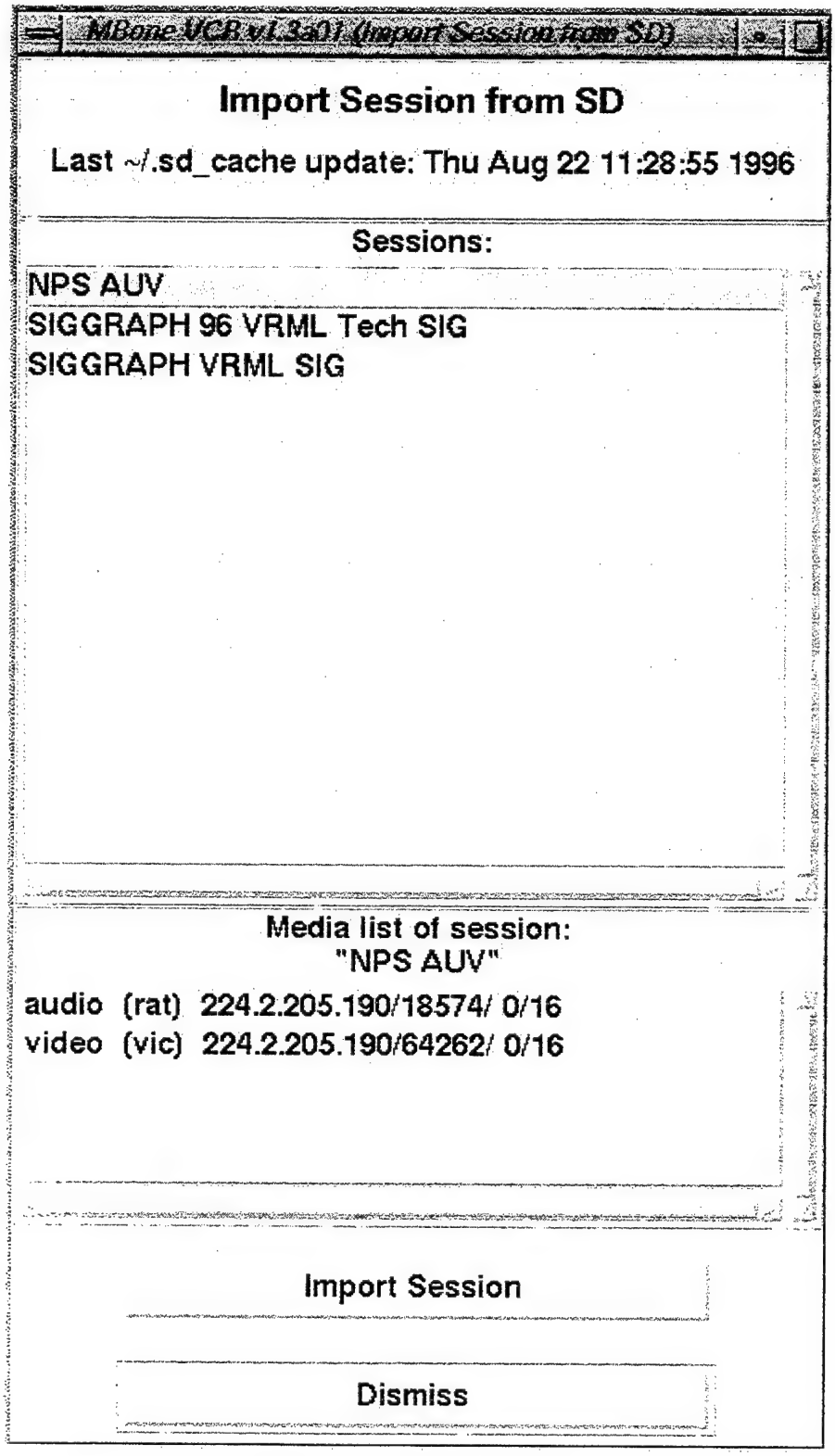

Figure C.3. Import Session

CREATE A SESSION

To create a new (empty) session a user can either use the "New Session..." entry in the "Session" menu or double click in the empty media list below the "No session" label. If you create a session manually, a session name and an optional session description have to be specified in the "New Session" window (Figure C.4). The "Max Scope" defines the maximum scope for all media included in this session. To add a new media to the session click on the "Add Media" button.

In the "Add Media" window (Figure C.5) a media name and an optional media description as well as the multicast address, the port number, the conference id (only needed for RTPv1 and *vat*), the protocol (RTP or vat) and the scope for this media need to be specified. Specifying a media command which will be used by the "Start Session Tools" function in the "Tools" menu to start the appropriate application for this media is optional. At the end, a session file name (which has to end with ".VCR") has to be given to the session. Clicking on the "Session Filename" button will open a file selection box to choose a directory and filename.

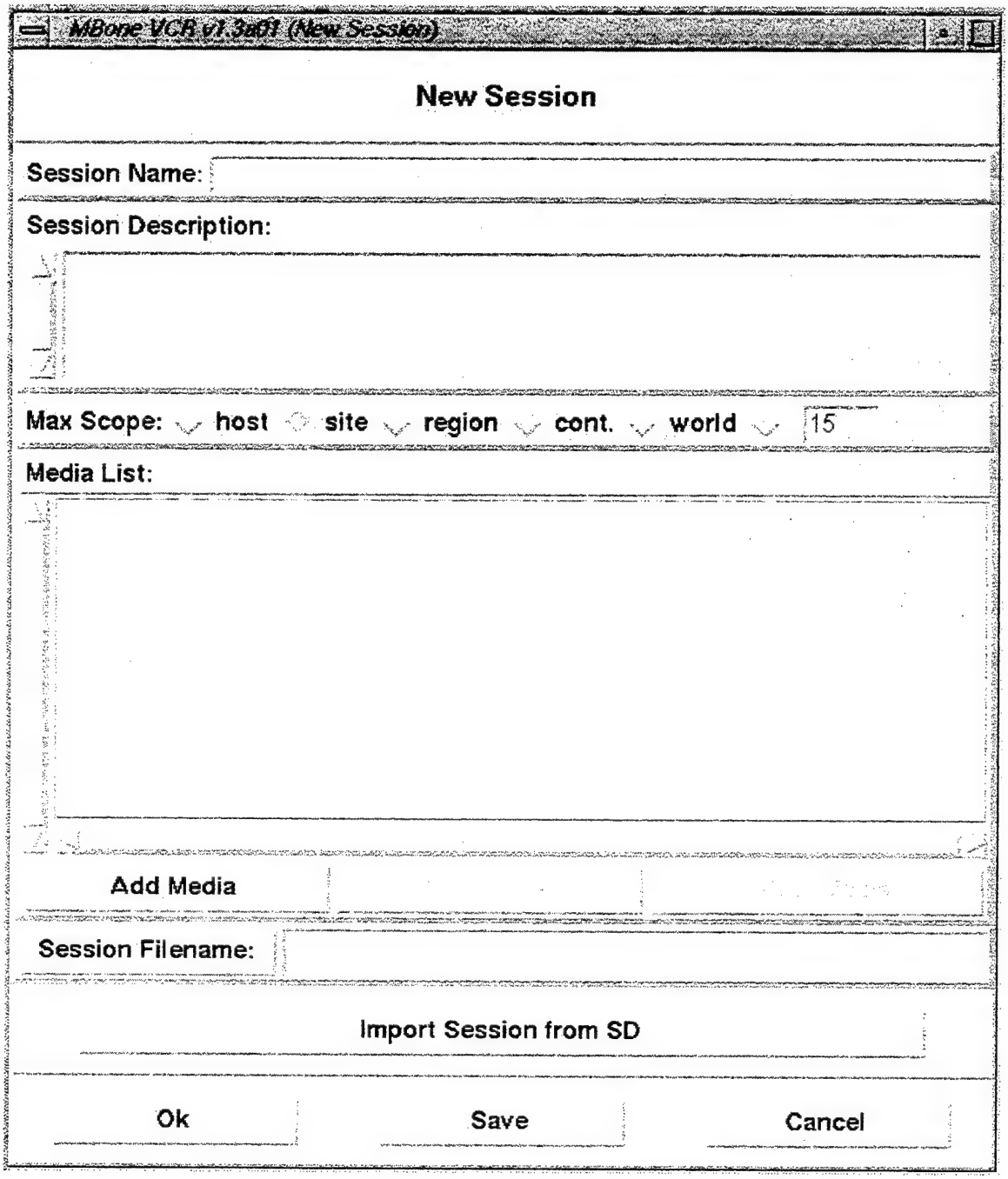

Figure C.4. New Session

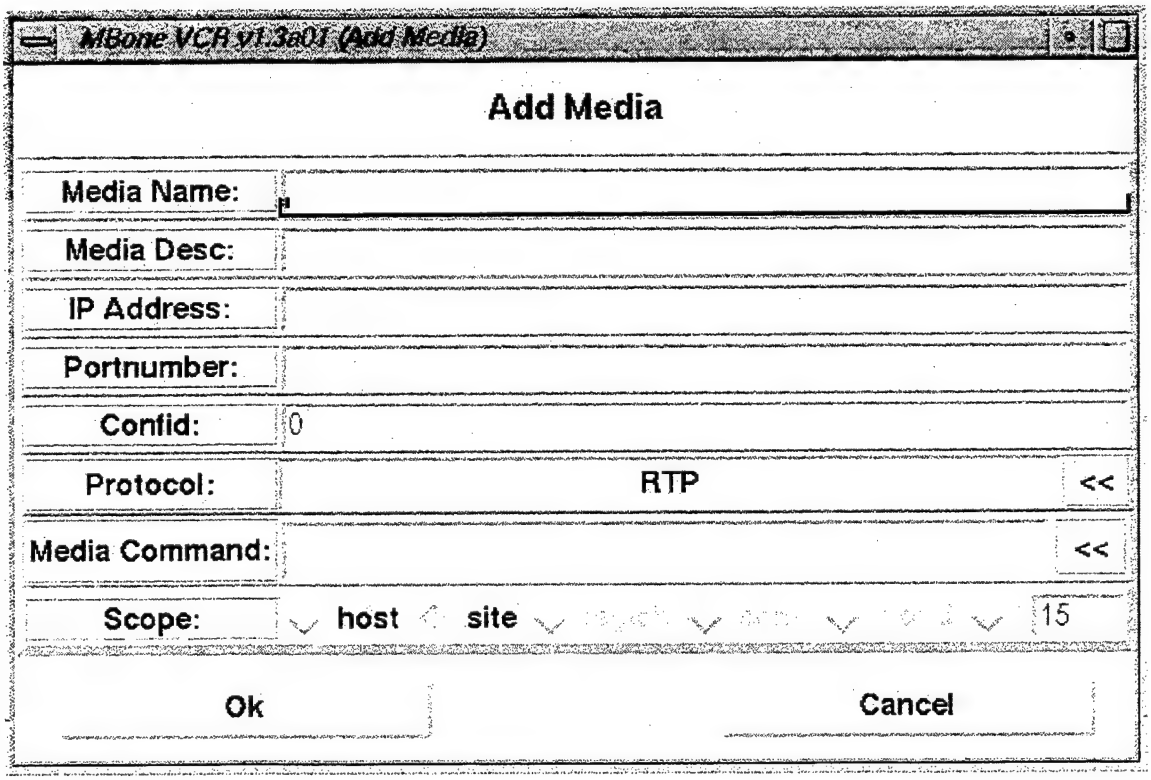

Figure C.5. Add Media

IMPORT MULTIPLE SESSIONS FROM THE SESSION DIRECTORY

With the "Import Session from SD" entry in the "Session" menu one can only import a single sd session. Sometimes, however, media that belong to one session are announced in different sd-sessions. To be able to record such sessions and rather than creating a VCR-session "by hand," one can use the "Import Session from SD" button in the "New Session" window to compose your VCR-session out of one or more sd-sessions. In the "Import Session from SD" window you will get two lists, a session list and a media list. These lists include all the sessions and media found in your `~/.sd_cache` file. The media list always displays the media of the selected session. If you select a different session, the media list will be updated automatically.

You can import an entire *sd* session (which is a session title, a session description, a generated session filename and all media supported by VCR) by clicking on the "Get Session" button or double clicking on a session entry in the session list. You can also only import a session title (together with a session description and a generated session filename) with the "Get Title" button (or by double clicking with mouse button 2 on a session entry in the session list). Another possibility is to add one or more media from sd-sessions to your existing VCR-session. To do this, you can select a media in the media list and then click on the "Add Media" button (or just double click on a media entry in the media list).

EDIT A SESSION OR MEDIA

After a session is loaded/created, the session name and a list of media is displayed in the status area. Double clicking on the session name will have the same effect as the "Edit Session..." entry in the "Session" menu. Double clicking on one of the media in the media list will have the same effect as the "Edit Media" button in the "Edit Session" window (Figure C.6). The "Edit Media" window is shown in Figure C.7.

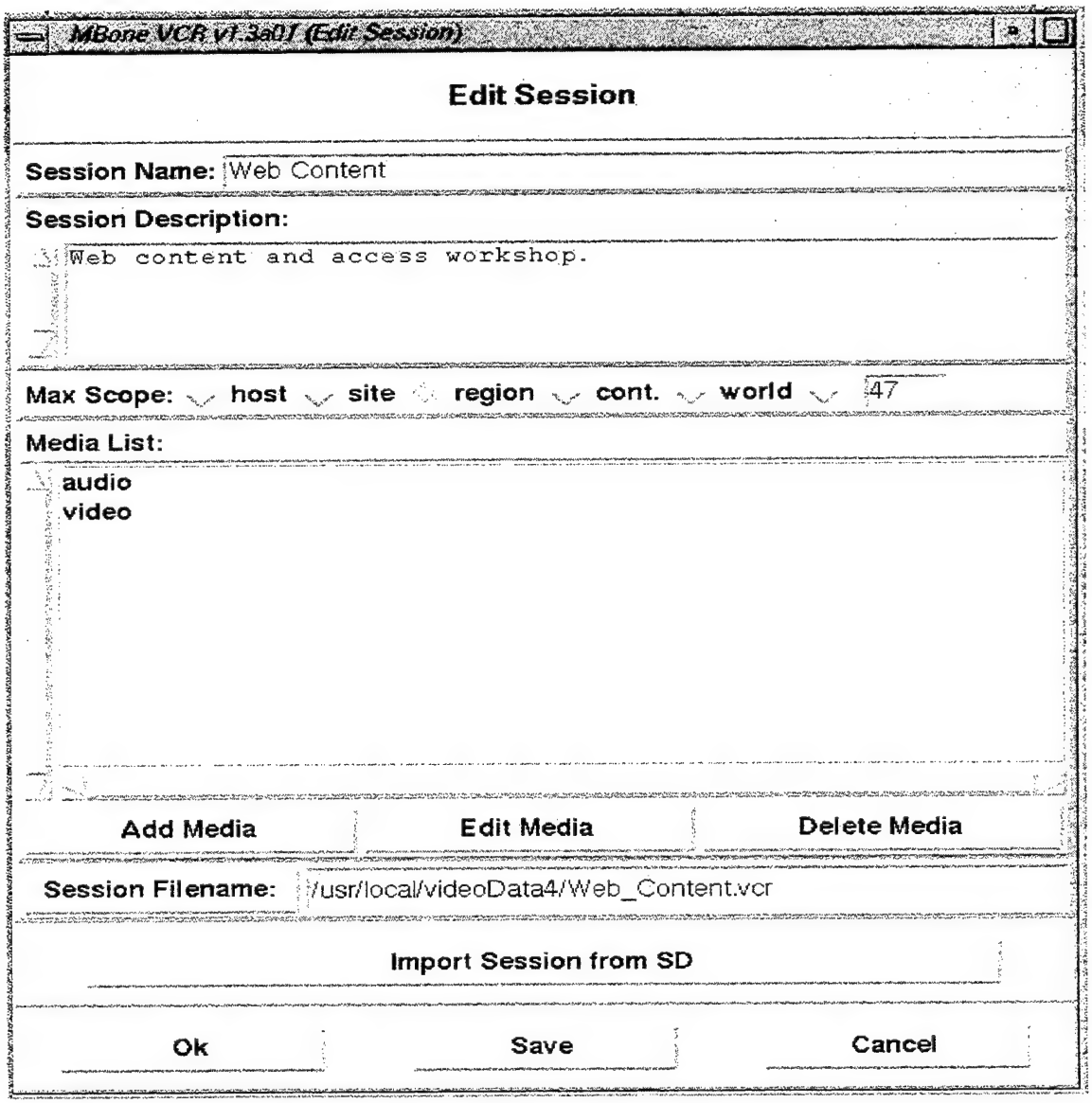

Figure C.6. Edit Session

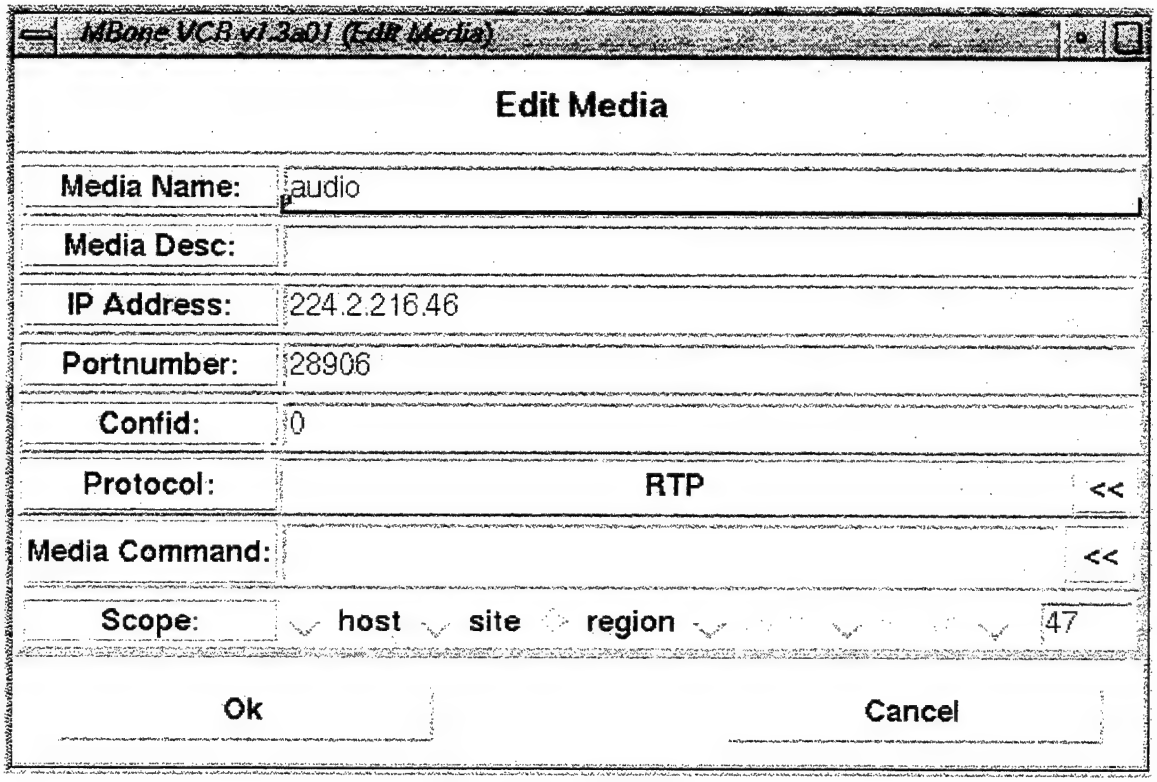

Figure C.7. Edit Media

MUTE A MEDIA

A single click with the left mouse button in the media list will select a media so it can be muted/unmuted with the "mute/unmute" button below the media list. If the media is muted, it is shown as "<media>" instead of "media." If more than one media is selected, the "mute/unmute" button will toggle the mute state for all selected media according to their mute state. Clicking on a media entry with the middle mouse button will toggle its mute state, clicking in the media list with the right mouse button will unselect all selected media. The mute/unmute interface is shown in Figure C.8.

Figure C.8. Mute/Unmute Interface

RECORD A SESSION

To record a session, you need to enable recording with the "Recording Enabled" entry in the "Record" menu (this step is important and easy to forget). By default, MBone VCR does not start to record if it does not receive a data signal from any of the media in the session. To start recording even when no data is present, select the "Start recording

without signal" checkbutton in the "Record" menu. To start recording click on the "record" button (third button from the left in Figure C.9). Click the "stop" button (fourth button from the left in Figure C.9) to stop the recording. In a non-empty session you can only append data so you have to go to the very end to continue recording.

Figure C.9. MBone VCR Function Buttons

Note:

In order to record your own signal, some tools require that the MBone VCR runs on a different host than these tools since they do not do local loopback of the multicast address/port combinations (e.g. *vat* and *vic*). Therefore the "Start Session Tools" window from the "Session" menu offers an entry field "Start tools on host" that will start the tools with an rsh command on the specified remote host. For this case it is required that your `~/.rhosts` file allow such operations.

Since MBone VCR does local loopback, you do not need to run it on a different host than the session tools if you only want to play a session back. In this case you could set the scope to 0 (host) so you won't send out any data to the network.

The "Stop Session Tools" entry in the tools menu will allow you to stop the started tools. It will look for the processes in the process table

(regardless whether they were started on the local or a remote host) and if they still run, it will send them a kill signal to stop.

PLAY A SESSION

To play a session back you simply click on the "play" button (third button from the right in Figure C.9). In order to listen and/or watch the data you need to run the corresponding MBone tools. These can be launched directly from within the MBone VCR with the "Start Session Tools" window in the "Tools" menu. If the option "Autostart Session Tools" in the "Tools" menu is selected, the "Start Session Tools" window will automatically appear when the user plays a session for the first time.

FAST FORWARD AND REWIND

To fast forward (ff) or rewind (rew) a session you can click on the "ff" button (second from the left in Figure C.9) or the "rew" button (second from the right in Figure C.9). The speed with which the session will be forwarded/rewound can be changed with the "FF/REW factor .." entry in the "Options" menu.

RANDOM ACCESS WITH THE SESSION SLIDER

The slider on the very bottom of the interface (shown in Figure C.10) enables random access within the session. Clicking with the middle mouse button somewhere in the slider will forward or rewind the session to this point. Clicking the left mouse button on the slider left from the marker will rewind the session one second, clicking the left

mouse button right from the marker will forward the session one second. If the right mouse button is clicked anywhere on the slider the session playback will pause until the button is released. At the lower right corner the total length of the session is displayed. Clicking in this field will forward to the end of the session.

Figure C.10. Random Access Slider

PLAYING AT VARIOUS SPEEDS

To change the playback speed you can select "double speed" or "half speed" in the "Speed" menu. Note that this feature is not available for all data formats. If multiple speeds for a format is not supported, you might mute the media to listen/watch at least the other media at double/half speed.

LOOP MODE

If the "Loop Mode" entry in the "Options" menu is checked during playback, the session will start all over from the beginning when it reaches the end. This feature allows continuously transmitting a session.

INDICES

The MBone VCR provides a number of different indices. Basically there are two categories of indices: automatically generated indices (AGI) and user defined indices (UDI).

AGIs are automatically generated by MBone VCR during recording. Examples for AGIs are "next speaker", "next sync unit" or "new format." UDIs can be set by the user either during recording or afterwards. There are five levels of UDIs so a user can use different levels for different purposes. To get/set/delete indices you can use the "Index Control Panel" by clicking on "Toggle indexcontrolpanel". The "Idxmode" menu will change the behavior of the leftmost and the rightmost button in the main window so you can select which function these buttons actually perform. This portion of the user interface is shown in Figure C.11.

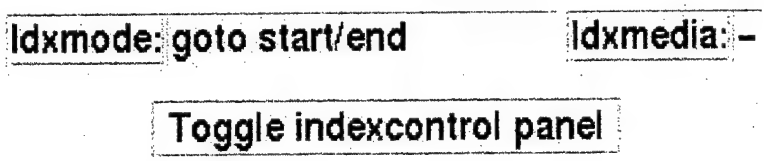

Figure C.11. Index Control Interface

Note:

Indices are always media specific so you have to specify an index media with the "Idxmedia" menu on which the index functions are performed. You can always change this media but you won't see indices set on one media if you have selected another.

BLANK SKIP / AUTO BLANK SKIP

One of the options in the "Idxmode" menu is "blank skip." This feature will skip blank gaps of the specified length in the media selected by the "Idxmedia" menu and forward the session to the beginning of the next data. "Blank Skip" and "Auto Blank

Skip" are basically the same, the only difference is that during playback "Auto Blank Skip" will automatically detect and skip blank areas in the media selected by "Idxmedia."

VCR MACRO COMMANDS

The VCR macro commands provide limited control to record and playback sessions during off-hours or to write macros for demo purposes. The supported commands are:

```
load
unload
play
rec
ff
rew
stop
at
      HH:MM:SS
      MM/DD/YY
wait
      [[[HH:]MM:]SS]
speed
      normal
      double
      half
goto
      end
      start
      secs
      next_index
            idx
      prev_index
            idx
      next_blank
            ms
      prev_blank
            ms
mute
      media_nb
      (0...nb_of_media-1)
auto_start
      on|off
blink
      on|off
idx_media
      media_nb
auto_blank
      ms
loop
      on|off
rec_enabled
      on|off
start_rec
      on_signal | no_signal
ff_rew_factor
      value
start_tools
stop_tools
```

These commands are documented in the VCR man page and can be used in a command file passed to the VCR applications by the "-c" command line parameter. A macro file can also be read with the "Run Macro File" entry in the "Macro" menu. The commands will be executed sequentially, a "wait" command will wait for hh:mm:ss until the next command is read, an "at" command (if not too late) will wait until the specified time/date. An example for playback might look like this:

```
# load a demo session (recorded earlier)
load ~/VCR-data/demo.vcr
# goto position 10 min.
goto 600
# start playing
play
# play for 5 min.
wait 5:00
# stop playing
stop
```

The macro commands can also be used to automatically start recordings at a specific time/date as in:

```
# load a demo session (created earlier)
load ~/VCR-data/demo.vcr
# start the session tools
start_tools
# goto end (recording is only allowed at the end!)
goto end
# enable recording
rec_enabled on
# start recording at 1:45pm on May 20th 1995
at 13:45:00 05/20/95
# start recording
rec
# record for 1 hour and 30 mins.
wait 1:30:00
# stop recording
stop
# close the session tools
```

```
stop_tools
# quit the MBone VCR
quit
```

Or another example could be to playback sessions of a conference recording at a specific time/date as in:

```
# no loop mode
loop off
# start playing at 12:00pm on May 20th 1995
at 12:00:00 05/20/95
# load conf1 session
load ~/VCR-data/conf1.VCR
# start playing
play
# play for 1.5 hours
wait 01:30:00
# stop playing
stop
# unload conf1
unload
# start playing at 2:00pm on May 20th 1995
at 14:00:00 05/20/95
# load conf2 session
load ~/VCR-data/conf2.VCR
# start playing
play
# play for 1.5 hours
wait 01:30:00
# stop playing
stop
# quit VCR
quit
```

For example, this macro could be stored in a file conf1-2.cmd and than executed by running:

```
VCR -c conf1-2.cmd
```

KNOWN BUGS/SHORTFALLS

This research used an early version of the MBone VCR thanks to the enthusiastic and expert support of Wieland Holfelder. This section delineates the know bugs and some of the shortcomings of the MBone VCR that will hopefully be corrected in future versions of the tool.

- ♦Not compatible with *sdr* except by manually entering proper address/port numbers.
- ♦No *rat* compatibility as of this writing, important for redundant encodings (FEC) of audio.
- ♦RTP Sender Reports and RTP Receiver Reports not yet implemented.
- ♦Whiteboard (*wb*) not yet supported.
- ♦No bandwidth limiting during playback, may be useful in global (ttl=127) sessions.
- ♦Additional recording is only possible at the end of a session.
- ♦Double and half speed not yet supported for all data formats (may not be possible).
- ♦TCL/TK support should be statically linked in binaries to eliminate need for users to download TCL/TK libraries.

APPENDIX D. *NPS CAMPUS NEWS* ARTICLES ABOUT IIRG AND CONTENT AND ACCESS WORKSHOP

September 6, 1996 -- Profs, Students Continue MBone Development

by Dale Kuska

In the hit movie Back to the Future, Dr. Emmitt Brown took a DeLorean sports car, a few odds and ends in his garage, added a little innovation and ingenuity, and created a time machine with little money.

Professors and students here at NPS have accomplished a similar feat. They took a connection to the information super-highway, computer hardware, software and equipment that already existed on campus, also used some innovation and ingenuity, and created a high-speed Internet classroom at a very low cost.

While we may not be able to travel through time, the classroom does take advantage of developing technology, the Multicast Backbone (MBone) which allows NPS to broadcast classes over the Internet to destinations all over the world. "We want to use the MBone more and more because of its broad applicability across the Internet, the fact that we can access a lot of people," said Professor Don Brutzman. "We would like to be able to teach classes here and have them accessible to the Navy over the Internet."

In order to increase development of the MBone, Brutzman says the clear thing to do was create a group of professors and students aimed at doing just that. So began the Information Infrastructure Research Group (iirg@stl.nps.navy.mil) and one of their first orders of business was to create a dedicated MBone classroom. How to do that was a question that needed answering.

"Our usual answer to a question of, how do you do something,' is to simply do it; so we did," explained Brutzman. "We looked around campus to see what was available to us. We found a workstation that had a projector capability. We got a network connection into the classroom, so that was a start. From then on, it was fairly straightforward stepping through our previous lessons learned. We added a camera and wireless microphone. We wanted to make the teaching as natural as possible, so we added an overhead transparency screen."

But alterations to the classroom didn't stop there, added Brutzman. Public Works installed a second screen and added another light switch, giving the group more control over the lighting. "Again, this is something that didn't cost us any money. We just asked Public Works to do something they are here to do and do very well," said Brutzman.

NPS's video-teleconferencing classrooms offered the IIRG a working model, Brutzman said. "We have learned from looking at the distance learning classroom down (in Root) hall, and we tried to incorporate what we learned. But we intentionally wanted to use assets that already existed here at the school, not spend money, and move forward, and now I think we have a working product," he added.

The IIRG has not only put together a working on-line classroom, but continues researching all areas of MBone and network technologies. "It appears we can send over a 128kbit/sec ISDN line, Marine Corps Maj. Lauren Mihlon's thesis is trying to show that. We now can record MBone digitally and put them on-line for retrieval. (Marine Corps Capt.) Mike

Tiddy's thesis is showing that. (Turkish navy Lt. j.g.) Murat Tamer's thesis is documenting that you can move all this equipment to an auditorium or conference on a wireless link. Basically, that this is like a mobile classroom because you can pick it up and use it in another location the next day. (Turkish navy Lt. j.g.) Ridvan Erdogan's thesis is showing we can send MBone audio and video to local schools, even over their relatively slow connection lines. He's worked with the county office of education in Salinas and a school in Soledad," explained Brutzman.

"We've also had a student looking at how we can internetwork the whole Marine Corps and Capt. Jim Nierle laid it out in complete detail. That was a very exciting thesis because of the possibilities it may bring," he adds. "The main thing is that our thesis projects some what support each other, and the group allows us to meet and discuss similar problems, so that we're not trying to reinvent the wheel."

Brutzman feels that internetworking is clearly the wave of the future in the Navy. "When a ship pulls in and ties up next to the pier, double-up the lines, hooks up to shore power, hooks up to shore telephone, the next thing on their check list ought to be hook up to the shore Internet connection. That way the ship's Local Area Network is connected to the global Internet or the Navy's Internet. We think it is inevitable that these things are going to emerge," Brutzman explained.

"The best example of that is how we do business right here at NPS. There's probably not a person on this campus that isn't impacted positively by our campus network in their everyday work. You couldn't rip it out of this campus if you wanted to, it's that powerful. And there's no reason to think it won't be equally as powerful and just as useful on Navy ships."

There are hurdles, however, to make MBone technology accessible to any Sailor. Brutzman feels that when Local Area Networks are implemented on ships, the door will be open for MBone technology to fleet sailors worldwide, and "we just want to be ready."

August 30, 1996 -- Web Builders Share "High Technology" Projects, Lessons Learned

by Barbara Honegger

On August 26, the I3LA Content and Access (ConAcc) Team -- a regional network of computer engineers, educators, researchers, and librarians -- gathered at NPS for a two-day "learning workshop" on building content and access on the World Wide Web. The Web is a subset of the Internet, the worldwide network of computer networks.

Despite the imposing name -- I3LA stands for Initiative for Information Infrastructure and Linkage Applications -- members of the all-volunteer ConAcc team stress the informality of their working group.

"The ConAcc Team is really just a way for anyone interested in developing Web content and access to learn from and help each other," said Victoria Welborn, head of the Science Library at U.C. Santa Cruz and coordinator/facilitator for the group. "We meet once a month, but there's never enough time to really get into the specifics of each other's projects," she said. "So we decided to get together for a longer period of time for members to 'show and tell' what they've been doing -- which became the workshop."

An exciting 'show and tell' it was. Members not only discussed, but in many cases demonstrated, their "examplar" web projects, including "Networked Ocean Science Research and Education, Monterey Bay"; a mobile, online classroom using a "telemation" vehicle; "A Place of Our Own" -- a branch of the Santa Cruz library system set aside just for teenagers, to do homework and use computers; the Monterey Bay Area Cooperative Library System; and panels on reducing barriers to access, how to build user-interactive web pages, curriculum questions and Internet training for faculty and students.

"Our members were both pleased and proud," said Welborn. "Attendance was impressive-- over 40 on the first day and 20 on the second -- and we achieved all of our main goals: to educate and motivate each other, increase visibility and regional awareness for the network, recruit new members, and show how the technology actually works."

Throughout the workshop, for instance, presenters were able to project their Web sites and home pages "live" onto an overhead screen using an LCD panel, thanks to the efforts of NPS professor Don Brutzman and his dedicated team of students who manned the projection booth. They also provided a demonstration of "live" audio and video over the Internet using the "Multicast Backbone" (Mbone).

"Don Brutzman is part of the heart and soul of this effort," said Welborn. "Without him, none of it would have happened so soon, or nearly so well."

I3LA and its three teams -- network design, education and content-access -- formed two years ago when Pacific Bell agreed to provide free wiring into schools, research labs and libraries in Monterey and Santa Cruz Counties and two years of free telephone service for Internet users at the wired sites. Local institutions were quick to take advantage of this California Research and Education Network (CALREN) agreement, creating a regional network connecting K-12 schools, colleges, universities, museums, libraries, government agencies and research institutions in the two-county area.

So far, the regional network, called Monterey BayNet, has connected most users around the common theme of environmental and ocean science, providing full Internet access via text, hypertext, multimedia, audio and video. Forty five schools, libraries and colleges now have medium-speed links, and ten universities and research institutions high-speed connections, in the two counties.

"Although the initial, and therefore most developed, focus has been on science and ocean topics," said Welborn, "it is just that, a focus. It's not a limitation. People are free to use the Internet, individually or in teams, to look at anything they want to."

"This broad-based, collaborative effort teams education, science, business and government to fundamentally improve our schools," said Brutzman, a key member of all three I3LA teams. "Now that the connectivity is there, our mission is to promote practical uses for the network, and to serve users, creators and managers of data and information by facilitating access, building content, evaluating resources and maintaining collection."

The broad reach of the regional network can be seen from the list of workshop attendees and participants, which included representatives from UCSC; NPS; DLI; CSU; MIIS; Cabrillo College; AMBAG; Monterey County; San Juan Batista, Carmel, Santa Cruz County and

Monterey Bay Area Cooperative libraries; PRC; MBARI; the Monterey Bay Aquarium; the Monterey Bay National Marine Sanctuary; Moss Landing Marine Labs; Santa Cruz County Office of Education; Monterey Bay Online; and The Creative Edge.

According to Brutzman, "people" challenges have been and continue to be as important as technical ones in creating, building and maintaining the regional Internet system.

"One of our mottos is, 'Technical problems have technical solutions, and people problems have people solutions,'" he said. "Our goal is to make the high-tech Internet available and useful to real people in real jobs, every day."

In a few weeks, the job of maintaining the network may become a lot harder. As of October 1, the two-year CALREN agreement under which Pac Bell provided free wiring and phone time expires.

"We're at a very exciting junction after two years of free connectivity," said Bruzman. "We're going to have to find sustainable ways of keeping the schools connected. And now that we have a network, that's more important than ever." Anyone interested in joining the Content and Access Team, or with ideas about how to keep the network vital and growing, is invited to contact Welborn at 459-2816, or e-mail <welborn@cats.uscs.edu> or <i3la_conacc@mbari.org>. More information about the workshop is available at: <http://www.stl.nps.navy.mil/~brutzman/workshop.html>. And if you missed the workshop, you can still see the "live" audio and visual MBone in operation by dropping by Root Hall, Room 204 this Saturday, Sept. 14, Discovery Day, between 10 a.m. and 3 p.m.

LIST OF REFERENCES

Biggs, Christopher H., *Distance Education: A Case Study with Applications for DoD and the Marine Corps*, Master's Thesis, Naval Postgraduate School, Monterey California, June 1994.

Brutzman, Don and Emswiler, T., "MBone Unplugged," online home page, Naval Postgraduate School, Monterey California, August 1995. Available at *http://www.stl.nps.navy.mil/~brutzman/unplugged.html*

Chen, Zhigang, and others, "Real Time Video and Audio in the World Wide Web," paper presented at the Fourth International World Wide Web Conference, December 11-14, 1995. Available at *http://choices.cs.uiuc.edu/Papers/New/vosaic/vosaic.html*

Davies, Bruce, "Lab's Connection to the MBone Wins '95 R&D 100 Award," *LBL Currents*, online magazine, July 1995. Available at *http://www.lbl.bov/ICSD/MBONE/current.html*

Emswiler, Tracey, *Internetworking: Worldwide Multicast of the Hamming Lectures for Distance Learning*, Master's Thesis, Naval Postgraduate School, Monterey California, September 1995.

Erdogan, Ridvan, *Internetworking: Using Global ATM Networks for Live Multicast Audio/Video Distribution*, Master's Thesis, Naval Postgraduate School, Monterey California, September 1996. Available at *http://www.stl.nps.navy.mil/~iirg/erdogan/thesis.html*

Frederic, Ron, Network Video Conferencing Tool ftp Site, April 1996. Available at *ftp://*parcftp.xerox.com/pub/net-research/nv-3.3beta/

Gambrino, John R., *An Analysis of Internet's MBone: A Media Choice Perspective*, Master's Thesis, Naval Naval Postgraduate School, Monterey California, September 1994.

Handley, Mark, conversation with Don Brutzman at SIGCOMM '96, Stanford California, 27 August 1996.

Herrmann, Eric, *Teach Yourself CGI Programming with Perl in a Week*, first edition, Sams.net Publishing, 1996.

Holfelder, Wieland, "MBone VCR - Video Conference Recording on the MBone," paper presented at the Third ACM Conference on Mutimedia, ACM, San Francisco California, 1995.

Holfelder, Wieland, "The MBone VCR Page," online home page for the MBone VCR, a Video Conference Recorder for the MBone, September 1996. Available at *http://www.informatik.uni-mannheim.de/~whd/mbone-vcr/*

Honegger, Barbara, "Web Builders Share 'High Technology' Projects, Lessons Learned," *Campus News*, vol. 3, no. 34, 30 August, 1996.

Information Infrastructure Research Group (IIRG), online home page, September 1996. Available at *http://www.stl.nps.navy.mil/~iirg/*

Internet Engineering Task Force (IETF) Request For Comments (RFC) 1889, *RTP: A Transport Protocol for Real-Time Applications*, by Schulzrinne, H. and others, January 1996. Available at *ftp://ds.internic.net/rfc/rfc1889.txt*

Internet Engineering Task Force (IETF) Request For Comments (RFC) 1890, *RTP: Profile for Audio and Video Conferences with Minimal Control*, by. and others, January 1996. Available at *ftp://ds.internic.net/rfc/rfc1890.txt*

Jacobson, Van and McCanne, Steven, "wb - LBNL Whiteboard Tool " online home page, September 1996. Available at *http://www-nrg.ee.lbl.gov/wb/*

Jacobson, Van and McCanne, Steven, "vat - LBNL Audio Conferencing Tool," online home page, September 1996. Available at *http://www-nrg.ee.lbl.gov/vat/*

Kahn, Jeffery, "Building the Internet's MBone: LBL's Van Jacobson a Principal Architect," LBL Science Articles Archive, December 1994. Available at *http://www.lbl.bov/science-Articles/Archive/MBONE-van-jacobson.html*

Kahn, Jeffery, "MBone -- Communications for the Next Millennium," *LBL Highlights*, online magazine, July 1995. Available at *http://www.lbl.bov/ICSD/MBONE/*

Keegan, Desmond J., "On Defining Distance Education," *International Perspectives*, 1983.

Klemets, Anders, "The Design and Implementation of a Media on Demand System for WWW," First International Conference on the World Wide Web: Conference Proceedings, May 1994. Available at *http://www.it.kth.se/~klemets/www.html*

Kumar, Vinay, "The MBone Information Web," online home page, supported by ICAST Communiciations Inc., August 1996. Available at *http://www.best.com/~prince/techinfo/mbone.html*

Kuska, Dale, "Profs, Students Continue MBone Development," *Campus News*, vol. 3 no. 35, 6 September 1996.

Macedonia, M. R. and Brutzman, D. P., "MBone Provides Audio and Video Across the Internet," *IEEE Computer*, vol. 27 no. 4, April 1994.

McCanne, Steven and Jacobson, Van, "vic - Video Conferencing Tool," online home page, September 1996. Available at *http://www-nrg.ee.lbl.gov/vic/*

Mihlon, Lauren R., *Internetworking: Extending Lan Connectivity Using ISDN*, Master's Thesis, Naval Postgraduate School, Monterey California, September 1996. Available at *http://www.stl.nps.navy.mil/~iirg/mihlon/thesis.html*

Norris, R. E., and West, D. *The Digital Library Phenomenon: Opportunities and Implications for the Naval Service*, Master's Thesis, Naval Postgraduate School, Monterey California, June 1996.

Partridge, Craig, *Gigabit Networking*, Addison-Wesley, 1994.

Progressive Networks, "Real Audio," online home page, June 1996. Available at *http://www.realaudio.com*

Rangan, P. Venkat; Vin, H.M. and Ramanathan, S., "Designing an On-Demand Multimedia Service," *IEEE Communications*, vol. 30 no. 7, July 1992, pp. 20 - 25.

Rettinger, Leigh Anne, *Desktop Videoconferencing: Technology and Use for Remote Seminar Delivery*, Master's Thesis, North Carolina State University, Raleigh, North Carolina, July 1995. Available at *http://www2.ncsu.edu/eos/service/ece/project/succeed_info/larettin/thesis/abs.html*

Senge, Peter, *The Fifth Discipline: The Art and Practice of the Learning Organization*, Doubleday, 1990.

Tamer, Murat, *Internetworking: Multicast and ATM Network Prerequisites for Distance Learning*, Master's Thesis, Naval Postgraduate School, Monterey California, September 1996. Available at *http://www.stl.nps.navy.mil/~iirg/tamer/thesis.html*

Turletti, Thierry, "IVS Home Page," online home page, September 1996. Available at *http://zenon.inria.fr:8003/rodeo/personnel/Thierry.Turletti/ivs.html*

University College London (UCL), "The RAT (Robust-Audio Tool) Home Page," online home page, September 1996. *Available at http://www-mice.cs.ucl.ac.uk/mice/rat/*

Wall, Larry, and Schwartz, Randal L., *Programming Perl*, O'Reilly & Associates, Inc., 1991.

Wood, Graeme, "The Multimedia Conferencing Applications Archive," online home page for the UK MICE National Support Center, September 1996.Available at *http://ugwww.ucs.ed.ac.uk/mice/archive/*

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